C.E.C. JOINT RESEARCH PROJECT "EFFECTS OF IMPULSE NOISE ON HUMAN BEINGS"

the field survey

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juli 1987

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Deze uitgave is te bestellen door het overmaken van *f* 21,20 (incl. BTW) op postrekening 20.22.77 van het NIPG-TNO te Leiden onder vermelding van bestelnummer 85008.

CIP-GEGEVENS KONINKLIJKE BIBLIOTHEEK, DEN HAAG

Groeneveld, Y.

"Effects of impulse noise on human beings": C.E.C. joint research project: the field survey / Y. Groeneveld, R.G. de Jong.
- Leiden: Netherlands Institute for Preventive Health Care TNO.
- Fig.
Met lit. opg.
ISBN 90-6743-057-9
SISO 614.63 UDC 614.872
Trefw.: geluidhinder

CONTENTS

SUMMARY

In their Third Environmental Research Programme for 1982/83 the Commission of the European Communities initiated joint laboratory and field researches on annoyance caused by impulsive sounds. Laboratory studies were carried out in several EEC countries (the UK, the FRG, Denmark, Italy and the Netherlands) while simultaneously field surveys were accomplished in the FRG, Ireland, France and the Netherlands. Laboratory and field teams consisted of experts from the several countries, mainly social and physical scientists, responsible for their own national research. Several joint planning meetings were held throughout the course of the project in order to ensure compatibility of results wherever possible.
The overall objective of the project was to compare the annoyance of impulse and continuous noises and to determine whether any adjustment to the impulse noise, expressed as an A-weighted equivalent noise level, is adequate in order to compare it to the continuous noise.
This report describes the findings of the Field Group, composed of the teams from France, Germany, Ireland and the Netherlands.

Within each country suited residential sites with impulse noise sources were chosen which were exposed to several types of industrial or shooting noise. Each site was divided into two or more zones with differences between impulse noise levels of at least 5 dB(A). In all zones residual or traffic noise was chosen as a reference for the impulse noise. Within each zone respondents were selected at random, which resulted in a stratified sample of 1615 respondents from the so-called "population at risk". Among other things they were questioned about annoyance caused by the total noise, by traffic noise and by impulse noise. The annoyance was scored on a non-verbal ten-point scale ranging from 0 to 9. Noise measurements of these three distinguished noises yielded equivalent noise levels during operation time of the impulse noise source and deduced equivalent 24-hour noise levels.
After combining noise data and social survey data it may be concluded that the 5 dB penalty for impulse noise as recommended by the ISO R1996 probably is too conservative.

A correction factor of at least 10 dB expressed as a difference between equivalent impulse and residual noise levels during the time of operation appears to be adequate. For levels expressed as equivalent 24-hours values the adjustment should even be at least 15 dB. This is quite logical because generally the operation times for the impulse noise were much shorter than those for the residual noises. The correction factors for three countries appear to match with each other rather neatly. Penalties in France are significantly lower. No conclusions can be drawn regarding the level dependency of the penalty upon both residual and impulse noise levels. Comparing annoyance from total noise with annoyance from impulse and traffic noise leads to the conclusion that a dominant model would be most appropriate when one wants to predict total annoyance from the other two.

C.E.C. JOINT RESEARCH PROJECT
"EFFECTS OF IMPULSE NOISE ON HUMAN BEINGS"
- THE FIELD SURVEY -

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1. INTRODUCTION

1.1 GENERAL

In their Third Environmental Research Programme for 1982/83 the Commission of the European Communities initiated and, together with four participating member countries, partially funded laboratory and field researches on annoyance due to impulsive sounds. There were two principal research co-ordinators: C.G. Rice (United Kingdom) for the LABORATORY GROUP and R.G. de Jong (the Netherlands) for the FIELD GROUP. The overall programme was monitored by P. Guillot of the CEC, Brussels.

The Field Group comprised two teams: a social survey team and a noise measurement team. The group was made up of the teams from the following four countries:

Federal Republic of Germany.
Medizinisches Institut für Umwelthygiene,
Düsseldorf.
(J. Kastka, U. Ritterstaedt)

France.
Société d'Etudes pour le Développement Economique et Social,
Paris.
(J.M. Rabrait)

Commins BBM,
Verrières-le-Buisson,
as an advisor because of their expert knowledge of noise measurements.
(D. Commins, A. Germon, M. Sidahmed)

Ireland.

Institute for Industrial Research and Standards (noise measurements), and
The Economic and Social Research Institute (social survey),
Dublin.
(B. Hayden, B. Whelan)

The Netherlands.

TNO Research Institute for Environmental Hygiene,
Delft.
(R.G. de Jong, Y. Groeneveld, R. van den Berg).

United Kingdom.

Institute of Sound and Vibration Research and
The Department of Social Statistics,
Southampton University, Southampton,
as an advisor, because of their expert knowledge
(C.G. Rice, J.G. Walker, P.H. Cooper)

1.2 HISTORY OF THE PROJECT

In their Second Environmental Research Programme for 1980/81 the Commission of the European Communities initiated a new line of research. This was the line investigating the effects of impulse noise on human beings. In this period a pilot study was carried out which eventually led to the current field study. The participants in the pilot stage came from France, Ireland, the United Kingdom and the Netherlands. The aim of the study was to get an idea of the prevalence of impulse noises. The results of the pilot study, reported earlier [1,2], have led to the current study which aims at investigating whether reliable dose-effect relations for more or less stationary impulse noise sources can be established.

In the pilot stage a common questionnaire was developed. This involved a lot of "trouble shooting" in the sense that the researchers had to develop routines to overcome difficulties of language and culture, difficulties of working together in an international setting, communicating over long distances.

This questionnaire formed the framework for the one used in the current study. Of course not exactly the same questionnaire could be used because the aim of the study had changed.

1.3 PURPOSE AND SUBJECT

The main purpose of the project was to determine whether impulse noise is more annoying than (continuous) traffic noise or not and if so, to establish the size of the difference in terms of the L_{Aeq}. The studies were carried out using the same methods in all participating countries.

This report describes the findings of the Field Group composed of the teams from France, Germany, Ireland and the Netherlands.
It is based upon the four national reports, from France [9], Germany [8], Ireland [10] and the Netherlands [7] as well as upon common analysis of all rough data from the four countries.
Main results of the field survey already have been published in the IMG-TNO report D91 [13], of which this report is an extension. Both these reports replace the IMG-TNO reports D75 [4] and D78 [6].
Several other, mainly field survey reports on more or less preliminary international results already have been issued within this project [4, 5, 6, 11, 12] and one more on further and deeper analysis of the common international data will follow.

1.4 ORGANIZATION OF THE FIELD RESEARCH

The field study was carried out in parallel with a laboratory study which investigated the annoyance of impulse noise in the laboratory.

The laboratory and field groups held several joint planning meetings throughout the course of the project in order to ensure compatibility of results wherever possible. However, as each group had very different constraints placed upon it by the very nature of the studies involved, the research protocols and the experimental designs might be somewhat different.

In organizing the main study many of the experiences from the pilot study were used. To mention a few of those experiences:
- the very loose organizational matrix of the pilot stage was abandoned. One co-ordinator was appointed. Tasks were divided according to the individual expertise in the group and meetings were scheduled about every three months;

- a code book for the common coding of the social survey data was developed;
- computer programmes were developed to ensure that each team processed its data in the same way.

Working together to overcome the difficulties encountered in this joints study - which proved to be many and sometimes rather basic for succesful completion of a project where many experts are involved (all with their own attitudes, habits, routines and preferences) - makes this study unique in the sense that the same study was in fact carried out in several countries instead of four *different* studies on a similar topic.

2. DESIGN OF THE STUDY

2.1 GENERAL

As it was the main purpose of this project to determine whether impulse noise is more annoying than (continuous) traffic noise or not and if so, to determine whether any adjustment to the impulse noise, in terms of the L_{Aeq}, is adequate in order to compare it to the continuous noise the study was designed to search for:

- the annoyance caused in the community by certain specified impulse noises in the presence of different levels of road traffic noise;
- a technique to be used to obtain noise data that would describe adequately the noise environment within a specified site.

It was carried out using the same methods in all participating countries and it was taken care of that two noise sources were common to all countries:

- noise from shooting ranges;
- traffic noise as the dominant aspect of the residual noise.

These were used as references to compare the other (mainly industrial) sources too.

2.2 SAMPLE SELECTION

In each country suited residential sites were chosen which were exposed to several types of impulsive industrial or shooting noise.

Different sites with impulse noise sources were investigated: pile driving, scrapyards, metal construction sites, shunting yards, civil and military shooting ranges and ship building yards.

At these sites the impact of the impulse and other noises were measured. The results of these measurements were combined with the results of a social survey at the same sites in order to find correct descriptors for the annoyance caused by impulse noise. A uniform sampling strategy has been developed. Some preliminary noise measurements, unknown to the residents at a site, were carried out prior to the social survey. The purpose of this was to determine whether a given site, subject to impulse noise, was suitable for the project. An Area Reference Point (ARP) was chosen in that section of the site which was most exposed to the impulse noise.

Then, zones were defined within the sites in terms of the levels generated by the impulse noise source.
The zoning criteria were as follows:

- the reference zone, that is the most exposed in the site, was to have an impulse noise to residual noise ratio of at least 10 dB(A);
- a difference of at least 5 dB(A) (maximum level, fast time constant) for the impulse noise levels was required between zones.

In some sites a third zone was chosen with only residual noise (without impulse noise) to be used as an "anchor" to be compared with the zones with impulse noise.
Additional zones were defined later in order to distinguish them within initial zones.
Residual noise mainly consisted of traffic noise.

In addition each zone had to be able to provide for a sufficient number (about 20) of interviews to be conducted. Within each zone respondents were selected in such a way that the sample was representative for the population at risk in this zone. The population at risk was defined as "people who are at home at least three days a week when the impulse noise source is in operation, and who are 18 years or older".
A stratified sample of respondents was drawn from this population by selecting dwellings in a zone at random, if not all were chosen. Per dwelling one respondent, meeting the selection criteria, was selected at random.

Tables 1 and 2 present the result of the sampling procedure.

Table 1: Review of sample size - numbers per site and per zone -

Sites \ Zones	1	2	3	4	5	6	7	Total
Athis-Mons	50	50	50					150
Saint-Denis	44	69	39					152
Antibes	22	42	6	79				149
Haan	7	15	8	14		19	17	80
Solingen	25	21	10	8	10			74
Plettenberg	9	17	11					37
Resse	27	30	37	36				130
Ringsend	11	14	16	15	23			79
Blackpool	21	15	9	11	20			76
Rushbroke	15	26	21	23				85
Churchtown	14	26	45	21				106
Kileek	23	31	17	37				108
Bolnes/Ridderkerk	21	18						39
Sittard	23	15						38
Lekkerkerk	18	11	20					49
H.I.Ambacht/Zwijndrecht	22	17	32					71
Raamsdonksveer	19	9	21					49
Bussum	20	7	21					48
Driebergen	22	18						40
Vught	25	10	20					55
Total	*438*	*461*	*383*	*244*	*53*	*19*	*17*	*1615*

Table 2: Overview of sample according to country and source type.

Country Source (number/percentage)	France (451)	Germany (321)	Ireland (454)	The Netherlands (389)
Shunting yard (150/9.3)	Athis-Mons(150)			
Shooting range (530/32.8)	Antibes(149)	Resse(130)	Kileek(108)	Bussum(48) Driebergen(40) Vught(55)
Shipyard (124/7.7)			Rushbroke(85)	Bolnes/(39) Ridderkerk
Scrapyard (226/14.0)			Ringsend(79) Blackpool(76)	H.I.Ambacht/(71) Zwijndrecht
Metalworking (327/20.2)		Haan(80) Solingen(74) Plettenberg(37)		Sittard(38) Lekkerkerk(49) Raamsdonksveer (49)
Building site (152/9.4)	Saint-Denis(152)			
Dairy (106/6.6)			Churchtown(106)	

2.3 SOCIAL SURVEY

The translation of the questionnaire was monitored closely. After completion of the questionnaire in English, it was translated into French, German and Dutch by experts and translated back into English by other experts, to make sure the translation had been adequate. In the questionnaire possibilities for comparison with the laboratory study on some questions were built in. The questionnaires are presented in the national reports [7] [8] [9] and [10]. The field work of the social survey in the four countries was carried out between September 1982 and April 1983. In each country it was intended to question about 400 people. This has resulted in 1615 useful interviews. The questionnaire, which took about 30 minutes, consisted in broad outline of four parts:

- about the house and the environment in general (Q 1-12, English questionnaire);
- about noise and noise annoyance in general (Q 13-14);
- about the specific noise sources we were interested in (impulse sources and traffic) in particular annoyance and disturbance (Q 15-33);
- a classification section in which age, sex, education, number of people in the household and such-like items were dealt with (Q34-end).

2.4 NOISE MEASUREMENTS

After the interviews had been completed a noise monitoring campaign was conducted at each site over several days. Because of the bad weather conditions in the winter of 1982 and the spring of 1983 the noise measurements could not be finished before the end of August 1983. Two types of data acquisition were performed:

<u>First</u>: noise monitoring at the Area Reference Point (ARP). The purpose of these measurements was to characterize the pattern and the variation of the levels of the impulse noise source over three 24-hour periods: during the first period by the acquisition of series of A-weighted equivalent noise levels over one minute and during the second and third periods by the acquisition every hour of L_{Aeq}, L_{A1}, L_{A10}, L_{A50}, L_{A90}, L_{A95} and L_{A99}.

<u>Second</u>: by making simultaneous analogical tape recordings during the first period, both at the Area Reference Point, the Zone Reference Point and the Zone Secondary Point.

The aim of the recording at the Area Reference Point, which is the measuring point of the most exposed zone in the site, was to ensure a cross check and to record information about the nature of the impulse noise source as well as about the character of the residual noise. The recordings at the Zone Reference Points (ZRP) (defined as the measuring points, representative for the zones in question) were carried out to establish the relationship between the zones with respect to the impulse noise. The recordings at the Zone Secondary Points (ZSP) were intended as a check of the homogeneity of each zone.

Noise measurements used for this study included measuring impulse noise (from a particular source) residual noise (mostly representing traffic noise) and total noise. For each of these noises among others the following types of representative noise measures were derived (or calculated later):

a. the L_{Aeq} during the time the <u>impulse noise source</u> was operating (regular working hours for a <u>particular source</u>) for the distinguished noises abbreviated as LIMPOP, LRESOP and LTOTOP;

b. the L_{Aeq} during 24 hours, similarly abbreviated as L24IMP, L24RES and L24TOT.

L24TOT and L24IMP do not represent real life situations, because they are "normalized" noise levels for noises not occurring all the time. For residual noise levels, the L24RES may be a more realistic measure than the LRESOP, because traffic noise can occur throughout the day.

For some zones some noise data were lacking, due to practical circumstances, such as impossibility of measuring lower noise levels in the presence of other higher ones, for example in the Netherlands.

Generally, noise levels during 24 hours for general and residual noise are only known for zones 1, for other zones they could be determined from the measurements.

3. RESULTS

3.1 GENERAL

At meetings during the course of this project agreements were reached concerning the analysis to be carried out separately for each country and to be reported in each national report from the four participating countries. Common data analysis on all rough data from the countries has mainly been restricted to the earlier mentioned noise measures and questions, especially the noise annoyance questions. The results of this analysis is reported here.

3.2 DESCRIPTION OF THE SAMPLE

Apart from the reviews already given in Tables 1 and 2 the samples in the four countries can be described and compared with regard to the noise situations in the different sites as well as regarding specific answeres to questions from the questionnaire.
The noise situations have already been discussed extensively in the separate national reports and are only compared briefly here. Table 3 presents some statistics of each noise measure of interest: the number of respondents having valid noise values, the mean value, the minimum and the maximum value both for all countries together and for each of them separately. From this table it is evident that mean total and residual noise levels in France are highest and more or less equal in the other countries regarding operation time levels. Mean impulse noise levels are lowest in the Netherlands and highest in Germany. On an average impulse noise levels (and their ranges) are much lower than (those of) residual noise levels. It is quite clear that for certain noise measures in the Netherlands much information is lacking (much less valid values than respondents).

Table 3: Statistics for equivalent noise levels: a. during operation time of the total noise (LTOTOP), the residual noise (LRESOP), the impulse noise (LIMPOP); b over 24 hours of the total noise (L24TOT), the residual noise (L24RES), the impulse noise (L24IMP).
1. Valid number of values per measure (n), 2. mean, 3. minimum and 4. maximum for countries separately and pooled (low = a very low level, set at 20 dB(A)).

n / mean min. / max.	France		Germany		Ireland		The Netherlands		Total	
LTOTOP	451	64	321	59	454	59	360	58	1586	60
	45	75	51	73	48	70	48	68	45	75
LRESOP	451	63	321	57	454	57	360	57	1586	59
	44	75	46	73	35	71	47	68	35	75
LIMPOP	451	45	275	50	454	42	339	35	1519	43
	low	68	31	63	low	69	low	56	low	69
L24TOT	451	61	321	58	454	56	170	54	1396	58
	42	71	49	71	47	67	48	63	42	71
L24RES	451	61	321	57	454	56	170	53	1396	57
	41	71	49	71	47	68	46	63	41	71
L24IMP	451	43	275	45	454	37	339	31	1519	39
	low	63	26	59	low	65	low	51	low	65
N(total)	451		321		454		389		1615	

Table 4 presents correlation coefficients between all six important noise measures, calculated from individual data for all countries together. Strong relations emerge between operation time and 24-hour noise levels and also between total and residual noise levels. The first result is quite logical, the second one is evident because from Table 3 it appears that because of the generally lower impulse noise levels the total noise levels are mainly built up from the residual ones. The (cor)relation between total and residual noise on the one hand and impulse noise levels on the other hand is quite low (but for 24-hour noise levels stronger than for operation time noise levels). Both noise levels are rather independent of each other.

Table 4: Pearson correlation coefficients between noise data for all countries together. All coefficients, except "NS", are significant.

	LIMPOP	LRESOP	L24TOT	L24IMP	L24RES
LTOTOP	.1253	.9242	.9552	.1870	.9283
N	(1519)	(1586)	(1396)	(1519)	(1396)
LIMPOP		.0384 NS	.2570	.9805	.1534
N		(1519)	(1329)	(1519)	(1329)
LRESOP			.8780	.0676	.8817
N			(1396)	(1519)	(1396)
L24TOT				.3458	.9828
N				(1329)	(1396)
L24IMP					.2382
N					(1329)

Table 5 presents a classification of respondents according to both residual and impulse noise levels during operation time, both of these dichotomized at certain relevant noise levels also used later on in this report. Apparently relative lower and higher levels for both noises, necessary for further analysis, are sufficiently present.

Table 5: Distribution of respondents according to lower and higher residual and impulse noise levels during operation time.

L_{Aeq} (residual noise, operation time)	L_{Aeq} (impulse noise, operation time)		
	LIMP<=45	LIMP> 45	ROW TOTAL
LRES< 55	177	232	409
LRES>=55	431	679	1110
COLUMN TOTAL	608	911	1519

N.B. for the rest (94) not all these data are known.

Next the national samples have been compared regarding the social survey data (answers to the questionnaire). Firstly Table 6 presents the reported satisfaction with several issues concerning the living area of the respondents. It gives numbers and percentages of respondents having answered the questions 2, 3 and 6 by either "very" or "fairly satisfied"; neutral and negative answers are not included.

About 86% of all respondents is positively satisfied with the area in general, though the average satisfaction with the specific items is lower: 71%. Apparently, two thirds of the respondents are satisfied with the surrounding noise.

In France people react clearly less satisfied with most of the items, including the noise, which might be explained by the higher total noise levels in France. The other three countries differ less strongly from each other with regard to this matter.

Table 6: Satisfaction with living area both for all countries and per country.

PERCENT (N CASES)	FRANCE	GERMANY	IRELAND	THE NETH.	TOTAL
NO2	76.3	90.6	87.9	90.6	85.8
Area in general	(451)	(320)	(454)	(384)	(1609)
HO3	85.8	93.1	88.8	93.1	89.8
House - flat	(451)	(321)	(454)	(389)	(1615)
NO6A	54.3	81.0	68.6	84.9	70.6
Parks and open spaces	(444)	(269)	(452)	(370)	(1535)
NO6B	63.8	78.0	63.7	67.5	67.5
Public transport	(409)	(309)	(449)	(320)	(1487)
NO6C	64.7	85.6	78.0	89.5	78.5
Appearance of buildings	(448)	(319)	(449)	(381)	(1597)
NO6D	54.2	78.1	77.9	64.5	68.1
Quietness of the area	(450)	(320)	(453)	(389)	(1612)
NO6E	60.0	46.4	74.1	70.9	63.9
Close to shops	(450)	(319)	(451)	(385)	(1605)
NO6F	60.8	73.7	67.3	70.1	67.4
Keep up streets	(449)	(319)	(452)	(384)	(1604)
NO6G	40.8	73.5	73.9	70.2	63.6
Cleanness of the air	(446)	(313)	(445)	(369)	(1573)
N	451	321	454	389	1615

Similarly numbers and percentages of many other responses to the questionnaire, mainly used as classification variables, are presented in Table 7. In total four fifths of the respondents claim to hear traffic, while two thirds hear impulse noise from the source regarded. Between countries these proportions may differ somewhat: Traffic is heard by less people in Ireland and impulse noise is heard mostly in Germany. The distribution as to sex, an important classification variable, is not equal on an average: nearly one third is male and two thirds are female. This apparently is due to the fact that more women met the selection criteria set up for this sample, especially the criterium of being at home at least three days a week in order to be exposed to the noise more or less regularly. However, this distribution differs strongly between countries: in France there are nearly as many men as women, whereas in the other countries more women than men were interviewed. Another classification variable, the number of house owners, is almost equally distributed in the sample. Only in Germany the percentage of house owners exceeds that in the other countries significantly.

The third classification variable, the proportion of respondents working in paid employment, differs strongly between the four countries. This is very likely due to the different distribution as to sex, which looks roughly similar.

In contrast to this a fourth classification variable, having (economic) ties to the impulse noise source regarded, needs not necessarily concern the respondent, but any member of the family. Therefore the distributions in the countries are not similar as to that by sex. Though between the countries there are some differences, the percentage of families having (economic) ties to the impulse source is rather small in all cases. The fifth classification variable, the level of education, is deduced from the school-leaving age (or college). If this was below 18 years, the education was defined as "lower" and if it was with 18 years or older it was defined as "higher". The distribution of this variable differs largely between countries, but may also be regarded dependent upon and explained by the distribution as to sex, though not exclusively. Anyway, on an average almost one third of the respondents has received "higher education", one third is in paid employment and the same proportion are females.

Table 7: Percentages of specific answers to various questions from the questionnaire.

PERCENT (N CASES)	FRANCE	GERMANY	IRELAND	THE NETH.	TOTAL
J15	89.6	88.0	64.3	87.4	81.6
Hear traffic	(451)	(317)	(454)	(389)	(1611)
P23	69.1	78.8	68.9	63.8	69.7
Hear impulses	(450)	(321)	(453)	(389)	(1613)
Q45Sex	47.5	41.1	18.1	19.8	31.2
Number of males	(451)	(319)	(454)	(389)	(1613)
M35	44.2	55.6	46.7	42.4	46.7
House owners	(448)	(315)	(454)	(389)	(1606)
Q39A	57.2	39.7	8.6	14.0	29.7
Paid employment	(451)	(320)	(453)	(386)	(1610)
Q40	4.9	4.2	6.4	1.8	4.4
<Economic> ties	(450)	(312)	(453)	(387)	(1602)
Q38	46.9	29.1	15.5	26.5	29.6
Higher education	(450)	(320)	(453)	(389)	(1612)
N	451	321	454	389	1615

3.3 COMPARISON OF THE ANNOYANCE SCALES

Both for the total noise situation (question 14) and the impulse noise (question 28) and the traffic noise (question 20) the annoyance was established in two different ways. Firstly by a four-point verbal scale (a-questions) with the labels "not annoying (4) - a little annoying (3) - annoying (2) - very annoying (1)" and secondly by a ten-point scale (b-questions) with only the extremes labled (not at all annoying (0) - extremely annoying (9)).

Correlation coefficients (calculated per noise) between both kinds of scales are rather high (round .90) as well as for all four countries together and within each country, as can be observed from Table 8.

Table 8: Correlation coefficients between four- and ten-point annoyance scales for the discriminated noises both for all countries and per country.

Noise (Q's)		France	Germany	Ireland	The Netherlands	Total
Total	(Q14A-Q14B)	-.86	-.82	-.93	-.88	-.89
Traffic	(Q20A-Q20B)	-.88	-.83	-.92	-.90	-.90
Impulse	(Q28A-Q28B)	-.94	-.90	-.95	-.95	-.93

(note the negative signs due to reverse coding of the labels)

This indicates a strong qualitative relation between both scales, which can be investigated more quantitatively in two different ways.

The first method to compare the four- and ten-point annoyance scales quantitatively tries to find the scale value on the ten-point scale corresponding best with any (verbal) level of the four-point scale by calculating a suited statistic (mean, median, mode) from the ten-point scale for each level of the four-point scale. This has been carried out for each noise and each country separately as well as for all countries together. The results are summarized in Table 9.
As the median may be regarded as the best suited statistic in this instance the table gives the global impression that the best corresponding

values of the ten-point scale with the labels of the four-point scale are as follows:

Labels from four-point scale	Values from ten-point scale
Very annoying	9
Annoying	5
A little annoying	3
Not annoying	0

Table 9: Means, medians and modes of ten-point annoyance scale values per level of the four-point annoyance scale per noise and per country. Four-point scale levels are coded VA = very annoying, A = annoying, LA = a little annoying and NA = not annoying.

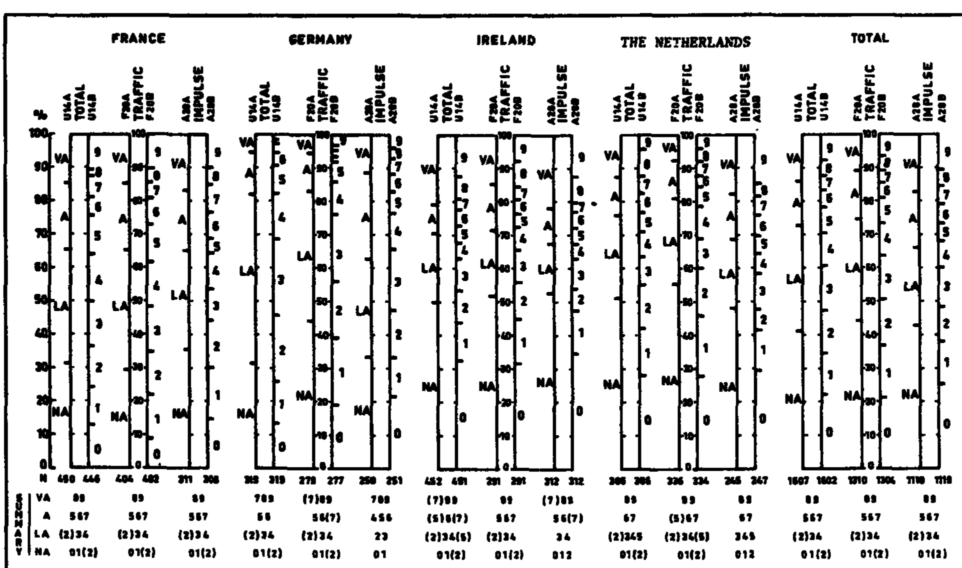
	FRANCE			GERMANY			IRELAND			THE NETHERLANDS			TOTAL		
	TOTAL	TRAFFIC	IMPULSE	TOTAL	TRAFFIC	IMPULSE	TOTAL	TRAFFIC	IMPULSE	TOTAL	TRAFFIC	IMPULSE	TOTAL	TRAFFIC	IMPULSE
Means															
VA	8.25	8.53	8.30	7.50	7.73	7.75	8.23	8.23	8.19	8.08	8.19	8.64	8.15	8.30	8.26
A	5.29	5.28	5.79	4.85	4.63	4.42	5.90	5.60	5.70	5.61	5.97	6.33	5.38	5.38	5.39
LA	3.42	3.45	3.14	2.89	2.82	2.55	3.33	3.18	3.43	3.53	3.17	3.67	3.26	3.18	3.13
NA	1.14	1.34	.92	1.08	.93	.61	.58	.69	.53	.85	.79	.68	.85	.91	.67
Medians															
VA	9	9	9	7.5	9	8	9	8	9	8	8	9	8.5	9	9
A	5	5	6	5	5	4	6	6	6	6	6	6	5	5	6
LA	3	3	3	3	3	2.5	3	3	3	3	3	3	3	3	3
NA	1	1	1	1	1	0	0	0	0	0	.5	0	0	1	0
Modes															
VA	9	9	9	9	9	9	9	8	9	8	8	9	9	9	9
A	5	6	6	5	5	3	6	7	6	6	5	7	5	5	6
LA	3	3	3	3	3	2	3	3	3	3	2	3	3	3	3
NA	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
N	446	402	309	319	277	249	451	291	312	386	331	244	1602	1301	1114

The second method for comparing the four- and the ten-point annoyance scales rather searches for ranges of ten-point scale values which are covered by the four-point scale levels than for only one value corresponding best. It relates the (cumulative) percentages of responses on the ten-point scale to those of responses on the four-point scale as they occur in this study.

The resulting relation is presented in Table 10 separately per noise and per country as well as for all countries together. The table shows the cumulative percentages of the scale values of both the four-point and the ten-point scale related via the same percentage scale ranging from 0 to 100%. For each relation it may be seen clearly what ten-point scale values correspond to what four-point scale levels. At the bottom of the table these similarities are summarized. Generally it may be concluded that the correspondence between both annoyance scales is as follows:

Labels from four-point scale cover	Ten-point scale values		
Very annoying	8	9	
Annoying	5	6	7
A little annoying	2(partly)	3	4
Not annoying	0	1	2(partly)

Table 10: Cumulative percentages of annoyance on both four- and ten-point scales per noise and per country. Categories of four-point scale may be related to those of ten-point scales and vice versa. Relating categories are summarized below. Four-point scale categories are coded VA = very annoying, A = annoying, LA = a little annoying and NA = not annoying. Ten-point scale categories are coded with whole numbers from 0 to 9 (0 = not at all annoying, 9 = extremely annoying).



Both just-mentioned methods yield slight differences between noises and countries, mainly due to casual factors, but between countries possibly also due to somewhat different semantic meanings of the translations of the verbal labels. On an average, however, the labels may be regarded as having nearly identical connotations in all four languages. They are as follows:

English	French	German	Dutch
not annoying	pas gênant	nicht belästigend	niet hinderlijk
a little annoying	un peu gênant	ein wenig belästigend	een beetje hinderlijk
annoying	gênant	belästigend	hinderlijk
very annoying	très gênant	sehr belästigend	erg hinderlijk

Only the annoyance scored on the ten-point scale has been used in further statistical analysis, especially in dose-response relations, for the following reasons:
- high correlation with four-point scale
- large similarity with four-point scale
- greater discriminating power than the four-point scale, greater precision

This section may be interpreted as a stamping and verification of the four-pointscale against the ten-point scale.

3.4 ANNOYANCE FROM THE DISTINGUISHED NOISES

Tables 11 and 12 present some statistics of the answers to the annoyance questions, measured at the ten-point scale, both separately and together for all countries. Table 11 mainly presents mean values for annoyance from single noises, while Table 12 mainly presents correlation coefficients between annoyances from two different noises. At first sight the impression from Table 11 corresponds to that from Table 3; the higher the (equivalent) noise levels the higher the average annoyance. This is especially well visible in France, where both the levels and the mean annoyance for total and residual (traffic) noise are higher.

Besides it is remarkable that where the mean annoyance scores for Germany, Ireland, the Netherlands as well as for all four countries together from traffic noise lie in about the same range as those from the impulse noise (Table 11) the mean noise levels for the impulse noise are strikingly lower than those for the residual noise (Table 3). This implies that impulse noise on an average already is as annoying as traffic noise at much lower equivalent noise levels and that at equal equivalent noise levels impulse noise probably is more annoying than residual (traffic) noise. Furthermore, while total and residual noise levels are about the same (Table 3), apparently the annoyance they cause is not: average traffic noise annoyance clearly is lower than annoyance from the total noise (Table 11).

Table 12 does not match too nicely with its comparable Table 4: though total and residual noise levels are related very strongly, the annoyance they cause is apparently less strongly related. On the other hand, while both total and residual noise levels are only weakly related to impulse noise levels, their respective annoyance scores appear to be related stronger. Though the aggregated annoyance data (means) seem rather well related to the noise levels of course, the individual annoyance scores are not.

In the next section the individual annoyance scores will be related to the noise data, giving dose-response and other relations, presented visually in the figures by way of graphs. Generally, these graphs present the relations in two different ways:

a. as linear regression lines representing the relation (with 95% confidence intervals);
b. as smooth curves, showing the shape of the relation as it exists in the sample quite realistically. This has been accomplished with the aid of the so-called smoothly shaped curve method (SSCM), which is discussed in detail in Appendix 3 of the Dutch National Report [7].

Within all graphs noise levels which are too low to be measured or even to be heard are fixed at 20 dB(A).

In general relations are established for both operation time noise levels and noise levels during 24 hours.

Table 11: Mean annoyance, its standard deviation (and number of respondents included) from the distinguished noises, measured at the ten-point scale, both per country and for all of them.

mean/ st.dev./ n	FRANCE	GERMANY	IRELAND	THE NETHERLANDS	TOTAL
TOTAL NOISE (Q14B)	3.8/2.7/446	2.8/2.0/319	3.2/3.3/451	3.0/2.9/386	3.2/2.8/1602
TRAFFIC NOISE (Q20B)	3.5/2.8/449	2.1/2.2/319	1.9/2.9/453	2.3/2.6/383	2.5/2.7/1604
IMPULSE NOISE (Q28B)	2.6/3.0/449	2.3/2.6/319	2.2/3.1/454	2.2/3.1/388	2.3/3.0/1610

Table 12: Pearson correlation coefficients (and number of respondents included) between the annoyance from the distinguished noises, measured as the score at the ten-point scale, both per country and for all of them.

r/n noise	FRANCE	GERMANY	IRELAND	THE NETHERLANDS	TOTAL
TOTAL TRAFFIC (Q14B-Q20B)	.78/446	.68/317	.59/400	.65/380	.67/1593
TOTAL IMPULSE (Q14B-Q28B)	.80/445	.45/317	.59/451	.56/385	.54/1598
TRAFFIC IMPULSE (Q20B-Q28B)	.44/448	.24/317	.47/453	.36/382	.40/1600

3.5 DOSE-RESPONSE RELATIONS

Dose-response relations (relations between noise levels and reported annoyance) are presented in Figure 1 for TOTAL, RESIDUAL, and IMPULSE noise as smooth curves, in which annoyance on the ten-point scale, the same as has been used in the simultaneous laboratory studies, has been related to corresponding equivalent noise levels during the time the impulse noise source is in operation (subjective scale value = SSV). Correlation and linear regression coefficients are also presented. Conclusions based upon this figure are equal to those based upon relations with noise levels expressed as 24-hour values, which are presented in Figure 2.

All relations appear to be positive, that is the louder the noise the more annoyance it causes. The (dependent) relation concerning impulse noise is strongest, for total noise weakest. The annoyance caused by impulse noise is higher than the annoyance caused by residual (traffic) noise for levels above about 45 dB(A).
Total noise annoyance (composed from whatever noises are present) is always higher than traffic noise annoyance, but not always higher than impulse noise annoyance. At higher noise levels (above 55 dB(A)) total noise seems less annoying than impulse noise.

A remarkable observation is that even the smooth curves show many fluctuations. These are possibly due to different reactions based upon different situations between zones. Each zone has its almost unique noise level because there is only one noise level per noise measure available for all respondents in a zone. Therefore possible differences between zones clearly show differences between noise levels, although the noise levels themselves are not the cause of these differences.

However, as these comparisons are made on grouped data, they are less reliable than comparisons based upon individual data (presented in the next paragraph). For example, higher total noise levels need not always be composed of both higher residual and impulse noise levels.

Fig. 1: Dose-response relation all noises (operation).

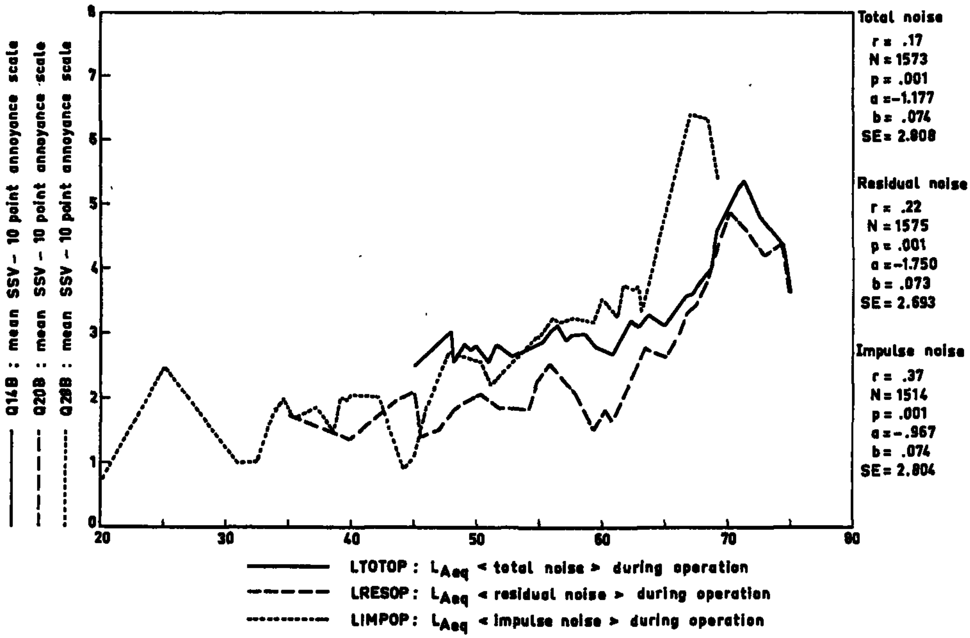
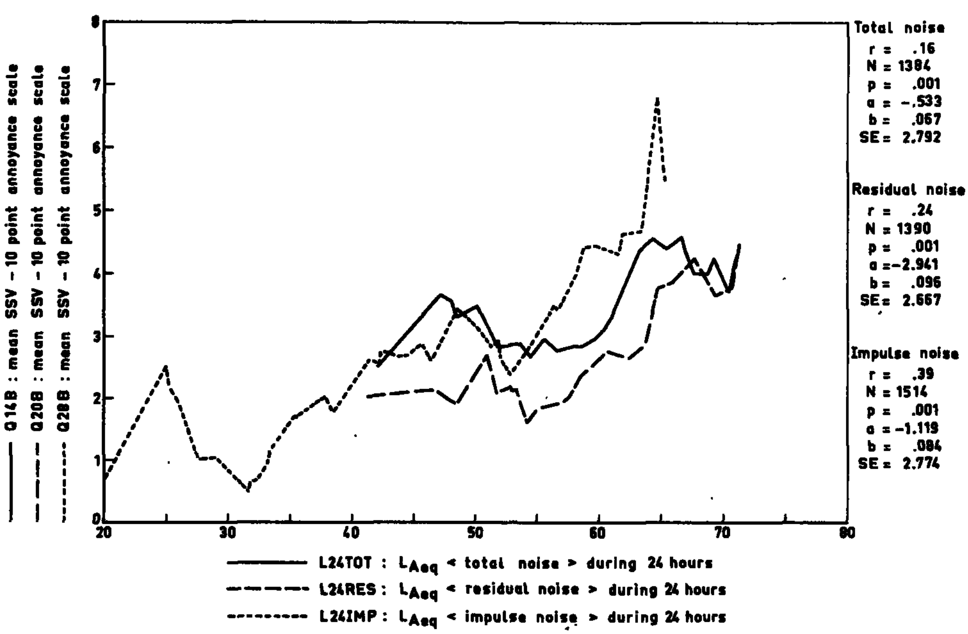


Fig. 2: Dose-response relation all noises (24 hours).



Because, generally, noise levels for impulse noise are based on 9 operation hours, their equivalent 24-hour noise levels are generally about 5 dB lower and so the relation between the two differs about 5 dB (shifts to the left for 24-hour levels). Generally, this is not the case for traffic noise levels: residual noise (which was measured) is rather constant during a longer period and hardly ever absent. Here the difference between operation time levels and 24-hour levels would not be so large and the dose-response relation would only shift a little to the left, resulting in larger differences between impulse and traffic noise annoyance for each noise level.

In the Netherlands for both total and residual noise levels during 24 hours much less data are available: these levels are not known for zones 2 and 3. This affects the strength of all relations based upon noise levels during 24 hours by decreasing their reliability to some extent.
The dose-response relations for traffic (residual) noise and especially for total noise appear to be quite weak, weaker than found in comparable studies (not referenced here). Besides for relations based upon 24-hour noise levels for which there is only a smaller number of noise data available, it also appears to be the case for relations based upon operation time noise levels. This might possibly be explained by the four following points:

1. Annoyance from traffic has been related with noise levels from residual noise, mainly consisting of traffic but also of birds, air plaines, railways, human voices, other industrial noise than impulse noise etc.
2. The residual and the total noise were measured at the same point as the impulse noise, which is not always the best point for measuring the other noises. In other studies concerning traffic noise, measurements were carried out at the most exposed points within an area or at the most exposed side of a house, while in this study it occurred that the impulse noise source was at the back side of a house (where the measurements were carried out) and the residual noise (e.g. traffic) occurred at the front side. This especially counts for zones 1 and 2.
3. In zones 2 and 3 and succeeding ones measurements only lasted for a short time (once or twice 15 minutes) and were difficult to relate to the first zone.

4. Per zone and per noise measure only one value for the noise level was determined representative for all respondents in that zone, reliable within ± 3 dB. Many different annoyance scores are related to that single value. The number of possible independent noise values is thus limited. The annoyance was measured more precisely than the noise and variation in annoyance is expressed insufficiently in variation in noise.

3.6 DIFFERENCE RELATIONS

From the former paragraph it appears that impulse noise is more annoying than (continuous) traffic noise at higher noise levels (> 45 dB(A)).

The approach up to now is a rather crude one. Using the regression lines comparisons are made between and not within respondents. People who are exposed to, for instance, 65 dB(A) from an impulse noise source are not necessarily the same people who are exposed to a traffic noise level of 65 dB(A).

Because there is a repeated measurements design (every respondent has annoyance scores and related noise levels for both total, residual (traffic) and impulse noise) it is possible to relate the difference in scoring annoyance from impulse and traffic noise to the same difference in corresponding noise levels, thus in addition eliminating many intervening influences within the respondents and enabling to establish the size of the penalty - if any - for impulse noise compared with more continuous noise.

On the other hand, in this case, where respondents are exposed to more than one noise, some kind of cumulation effect for the annoyance might be expected (a noise influencing the annoyance from the other noise). So the reported annoyance from a noise needs not to be quite the same as annoyance from that noise if a respondent is only exposed to that noise. That would mean that any penalty found here should mainly be regarded as appropriate for complex noise situations and any clean penalty should better be obtained from similar figures as discussed in 3.5 but concerning simple noise situations.

However, if two different annoyance scores might be influenced both (as here) by each others noises (e.g. increasing the annoyance somewhat) and if those two influences appear to be different, that difference will yet be assumed to be quite small in contrast to the absolute value of the annoyance measured. That means that, though annoyance may be influenced, any difference between two different annoyance measures (as will be considered here) might be regarded as to be (almost) free of such influences. Therefore we would regard any penalty, derived from this analysis as valid for both simple and complex noise situations. In Figures 3 and 4 differences in equivalent noise levels between impulse and residual noise were related to differences in annoyance scores per respondent between impulse and traffic annoyance.
These differences are presented as linear regression lines, with their 95% confidence intervals, and as smooth curves, based upon noise levels during operation time (Figure 3) as well as those during 24 hours (Figure 4).

From these figures the annoyance difference appears to be positive where the difference between the impulse and the traffic noise levels is zero, indicating that impulse noise is more annoying than traffic noise. Where the difference in annoyance is zero the difference between the equivalent noise levels during operation time of impulse noise and (continuous) residual traffic noise is about 11 dB(A). This may be regarded as a penalty for impulse noise. Using 24-hour noise levels a difference of 14 dB(A) is obtained. Both values differ significantly from the 5 dB penalty generally used. This implies that any penalty derived from these results would have to be at least 10 dB(A).

Fig. 3: Difference relation impulse-residual (operation).

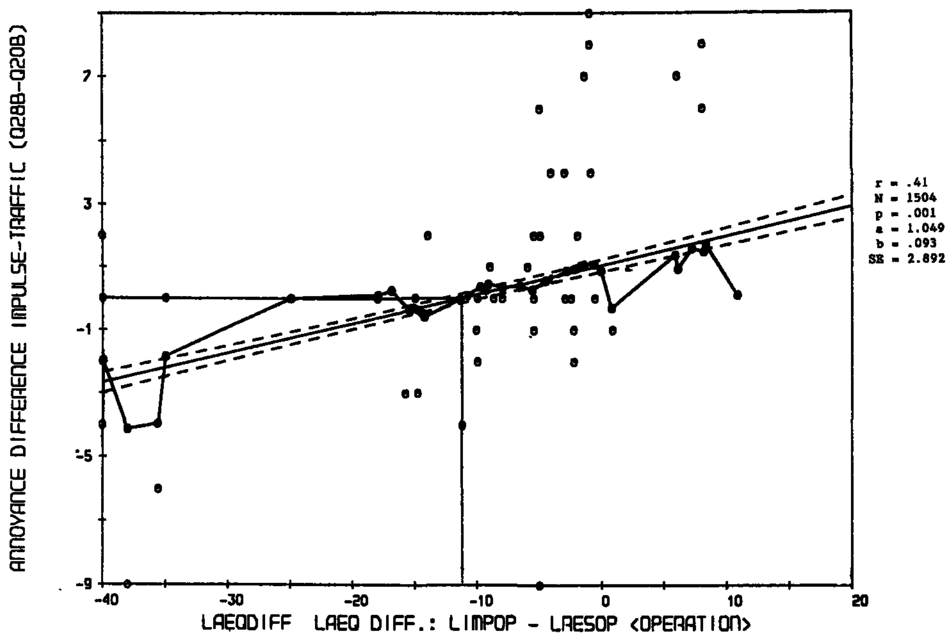
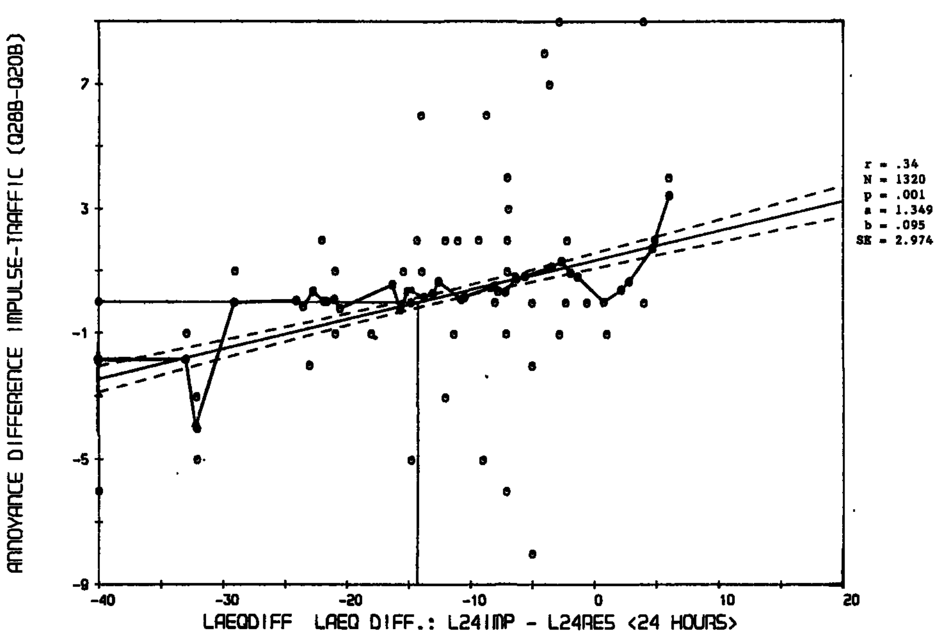


Fig. 4: Difference relation impulse-residual (24 hours).



3.7 DOSE-RESPONSE RELATIONS PER COUNTRY

Similar to Figure 1 dose-response relations with operation time noise levels are presented per country separately, not as separate figures including all noises per country, but per noise with four countries shown in one figure. Figure 5 shows the dose-response relations for the total noise, Figure 6 for the residual noise and Figure 7 for the impulse noise as smooth curves.

Correlation and regression coefficients are indicated in the figures, while similar figures with 24-hour noise levels are not presented, but similar statistics based on those noise levels are presented in Table 13.

Concerning total noise (Figure 5) it appears that the relations of the four countries do not differ too much. Striking is the Dutch relation which is not significantly dependent. All relations however are positive. Dose-response relations concerning residual (traffic) noise (Figure 6) show a rather complicated picture. From the corresponding linear regression lines, which are not presented here, it is quite obvious that the French relation differs significantly from the relations of the three other countries in that the annoyance from traffic noise in France is higher. This is important because this relation is used as a reference to impulse noise.

Dose-response relations for impulse noise (Figure 7) fluctuate rather much per country, but on an average only differ very little, as viewed from the corresponding linear regression lines, which are, however, not presented here. This means that impulse noise, just as the total noise, is experienced about equally in each country.

Fig. 5: Dose-response relation total noise (operation).

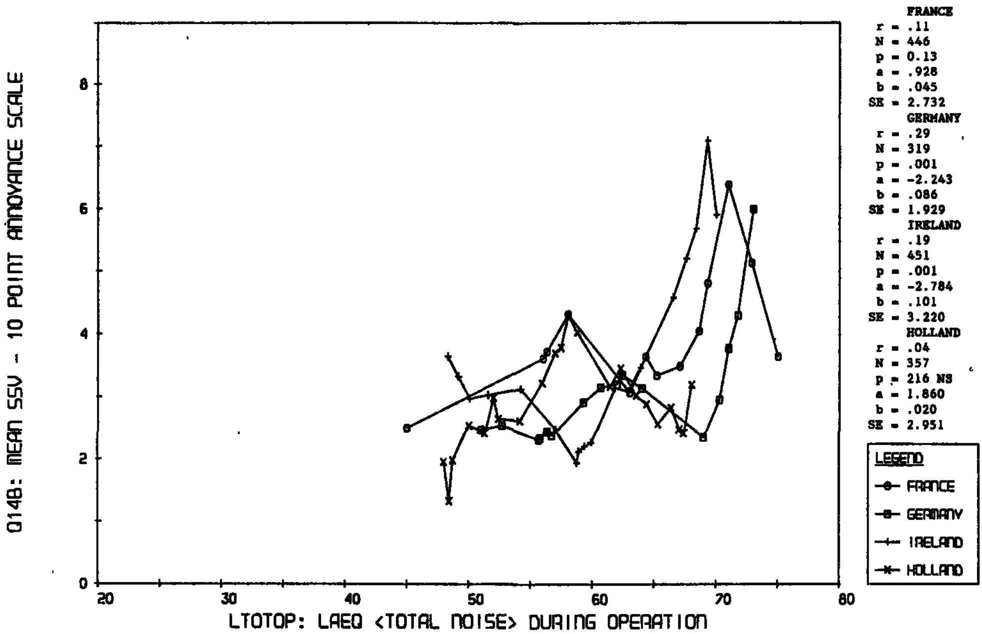


Fig. 6: Dose-response relation residual noise (operation).

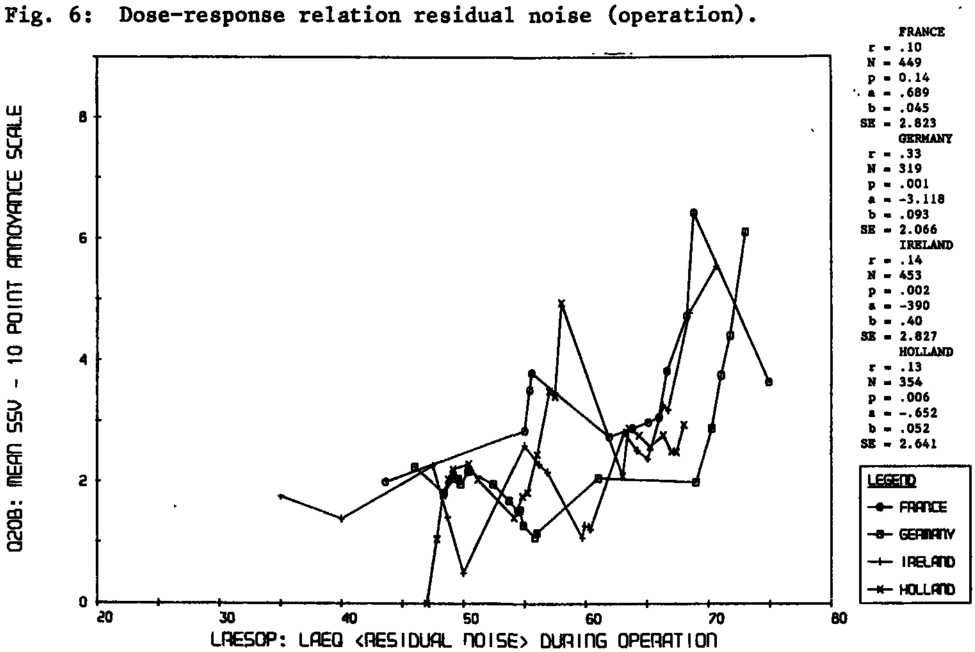


Fig. 7: Dose-response relation impulse noise (operation).

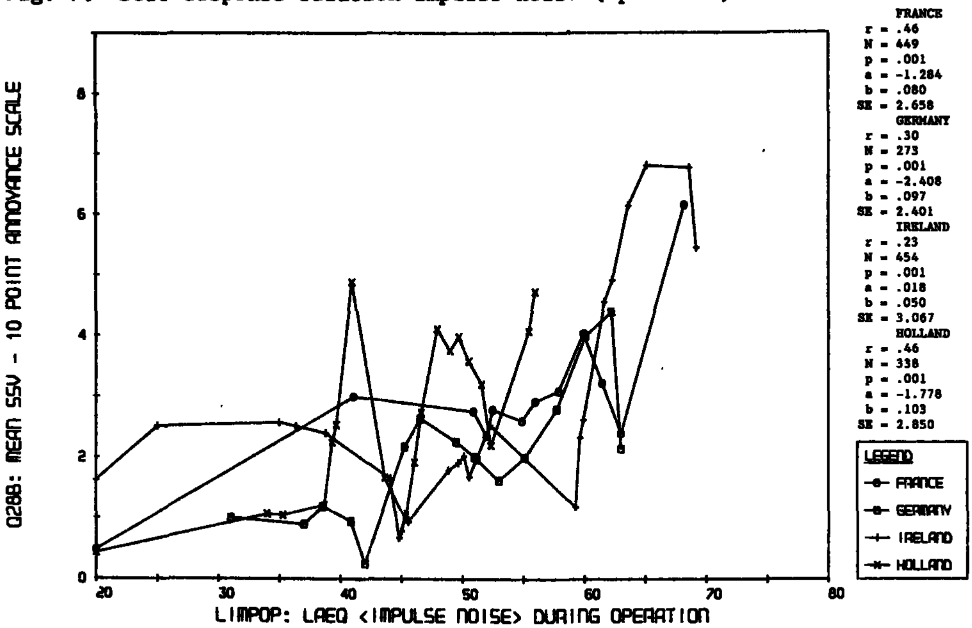


Table 13: Statistics from linear regression on dose-response and difference relations per country with 24-hour noise levels.
(NS = not significant)

COUNTRY / NOISE		France	Germany	Ireland	The Netherlands
	r	.08	.26	.24	-.05
TOTAL	N	446	319	451	168
(Q14B-	p	.043	.001	.001	.262 NS
-L24TOT)	a	1.911	-1.706	-4.364	5.431
	b	.031	.079	.135	-.032
	SE	2.739	1.945	3.182	2.903
	r	.07	.36	.22	.07
RESIDUAL	N	449	319	453	169
(Q20B-	p	.059 NS	.001	.001	.181 NS
-L24RES)	a	1.728	-3.919	-4.315	.476
	b	.030	.107	.111	.035
	SE	2.831	2.047	2.782	2.456
	r	.44	.31	.33	.49
IMPULSE	N	449	273	454	338
(Q28B-	p	.001	.001	.001	.001
-L24IMP)	a	-1.064	-2.132	-.859	-2.459
	b	.079	.101	.079	.135
	SE	2.699	2.392	2.973	2.790
	r	.45	.24	.28	.07
	N	448	271	453	148
DIFFER-	p	.001	.001	.001	.216 NS
ENCE	a	.567	1.271	1.625	1.992
	b	.109	.066	.080	.035
	SE	2.778	2.573	2.976	3.379

3.8 DIFFERENCE RELATIONS PER COUNTRY

Similar to Figure 3 difference relations have been established for each country resulting in the penalties already reported in the several national reports.

Figure 8 presents difference relations as linear regression lines with 95% confidence intervals based upon noise levels during operation time. Figures based upon 24-hour noise levels are not included, though concerning statistics are included in Table 13, but for both cases the penalties per country are deduced.

They are presented in the following table:

Table 14: Penalties per country in dB(A) based upon noise levels.

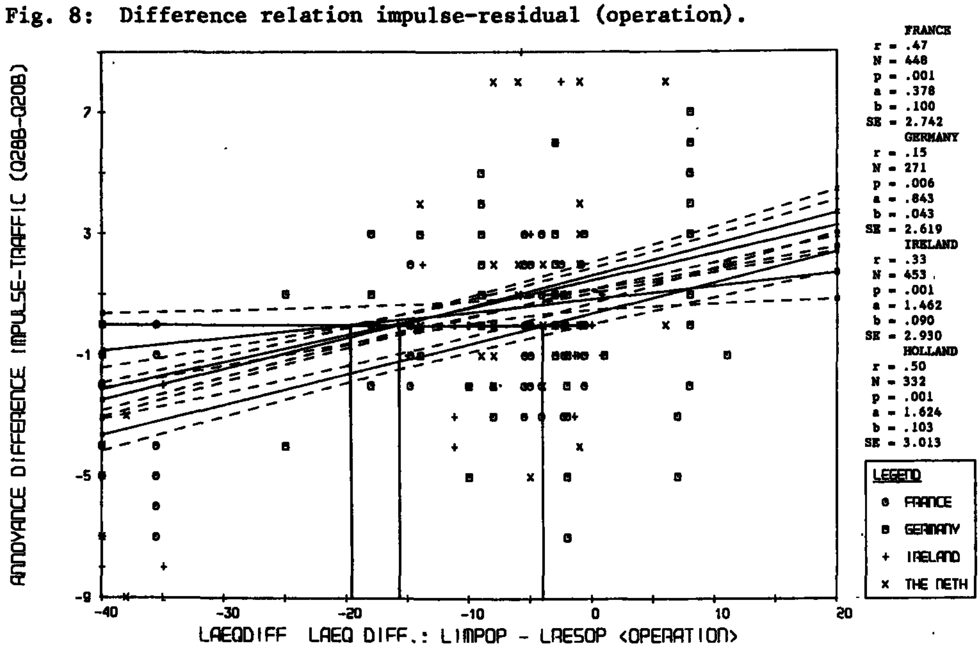
	during operation time	during 24 hours
France	4	5
Germany	20	20
Ireland	16	20
The Netherlands	16	> 40

It is clear that three countries (Germany, Ireland and the Netherlands) show the strongest agreement with each other concerning the value of the penalty being at least 15 dB(A) for operation time levels and at least 20 dB(A) for 24-hour levels. Including the French data these values decrease to respectively 10 and 15 dB(A).

An explanation for the devious French penalties is already given in the former paragraph.

The very large penalty in the Netherlands for noise levels during 24 hours is not quite realistic, because it is based upon a not significant difference relation in which the annoyance from impulse noise is always higher than that from the traffic noise, independent of the noise level difference. Therefore the indication "> 40" may also be interpreted as "unknown".

Fig. 8: Difference relation impulse-residual (operation).



3.9 SOURCE DEPENDENCY

There are eight different types of source and both dose-response relations and difference relations yield eight different lines some of them based on only one site with only two or three different noise levels. A thorough comparison is therefore not justified (see Figures 31 and 32 in section 3.14). An examination which is justified concerns comparisons between groups of source types, which includes several sites per group. Because, besides residual (traffic) noise, all national teams investigated shooting noise as a common impulse noise, it is of interest to compare this specific type of noise as a more or less homogeneous group to all other types of impulse noise.

Figures 9 and 10 present the dose-response relations for both shooting noise and all other impulse noise sources together using noise levels during 24 hours. In Figure 9 linear regression lines, with 95% confidence intervals, are shown, while in Figure 10 the same relations are presented as smooth curves. Statistics concerning these relations are included in Figure 9 and similar statistics from regression analysis with operation time noise levels are given in Table 15.

Fig. 9: Dose-response relation shooting vs. rest (24 hours).

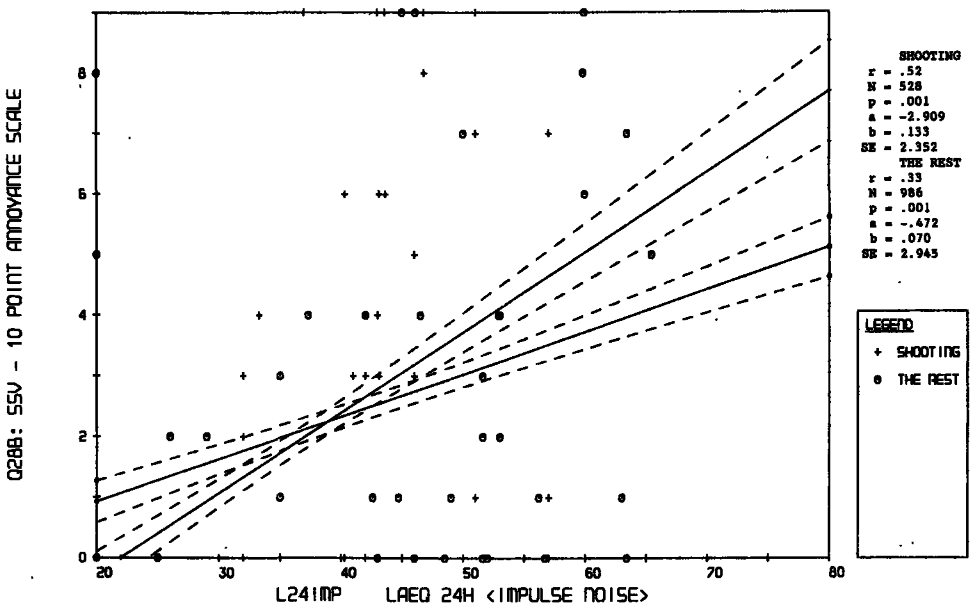


Fig. 10: Dose-response relation impulse noise (24 hours).

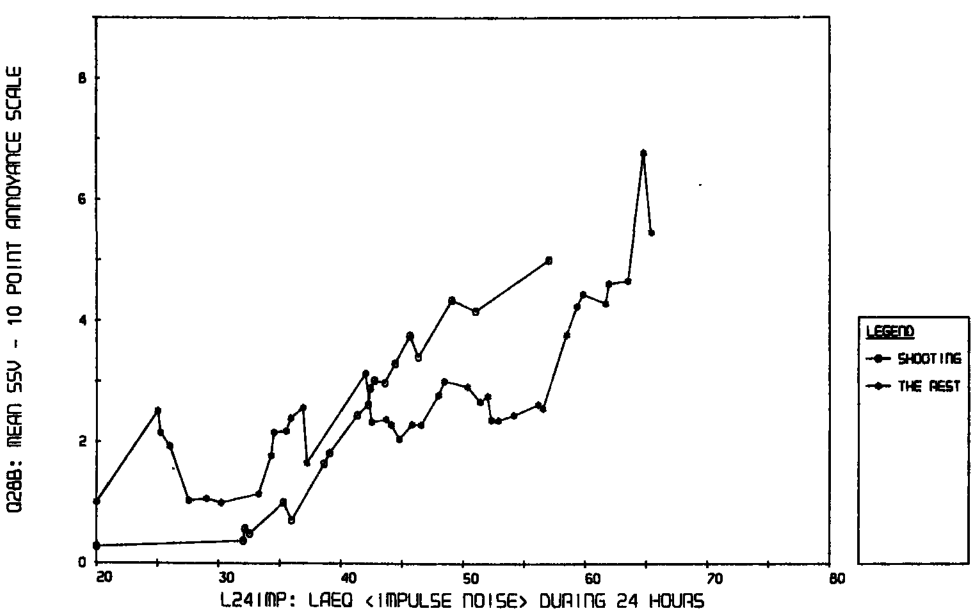


Table 15: Statistics from regression analysis on shooting ranges on the one hand and all other impulse noise sources on the other hand, based upon dose-response relations with noise levels during operation time.

	shooting ranges	other impulse sources
r	.43	.33
N	528	986
p	.001	.001
a	-1.922	-.471
b	.090	.066
SE	2.494	2.943

Table 16: Statistics from regression analysis on shooting ranges on the one hand and all other impulse noise sources on the other hand, based upon difference relations with noise levels during operation time.

	shooting ranges	other impulse sources
r	.55	.33
N	527	977
p	.001	.001
a	1.490	.797
b	.122	.075
SE	2.718	2.957

It may be seen quite clearly that shooting noise relations are stronger (a steeper slope and a higher correlation), especially regarding relations based upon noise levels during 24 hours. Using operation time noise levels shooting noise appears to be less annoying than the other impulse noise below about 50 dB(A), while above that level both groups do not differ significantly. For 24-hour noise values shooting noise seems to be more annoying than other impulse noise above 40-45 dB(A), equally annoying between about 35-45 dB(A) and less annoying below 35 dB(A). However, on an average both groups do not differ: average annoyance at average noise levels is the same, only in Germany a clear difference has been demonstrated: shooting noise appeared to be more annoying than the noise of a hammer mill.

The equivalence of both groups on an average is clearly visible in the difference relations for both groups, presented as regression coefficients in Table 15 for operation time noise levels and in Figures 11 and 12 including regression coefficients for noise levels during 24 hours. The linear regression analysis is shown in Figure 11 and the corresponding smooth curves constitute Figure 12.

The difference relations also show an interaction, but yield no different penalties. Apparently reactions to residual (traffic) noise between shooting and non-shooting sites are such that differences between them concerning difference relations are generally absent. This means that any penalty may be viewed valid for both types of sources.

As a third possibility one could compare sites within shooting ranges, thus comparing different kinds of shooting ranges, as there are gunfire and canon shooting (both military) and pistol and clay pigeon shooting (both civil). There are, however, only one or two of a kind and each site has only two or three different values for the noise levels. Because each kind is represented too weakly in the sample and there are too few data points (for the noise data) per site differences cannot be interpreted reliably and so will not be presented here. A final dichotomization possibly to be made is discriminating between permanent and temporary impulse noise sources, because the awareness of respondents about any future exposure time could influence their annoyance. But because there is only one temporary site in the sample (ANTIBES) any such comparison will be unreliable.

Fig. 11: Difference relation impulse-residual (24 hours).

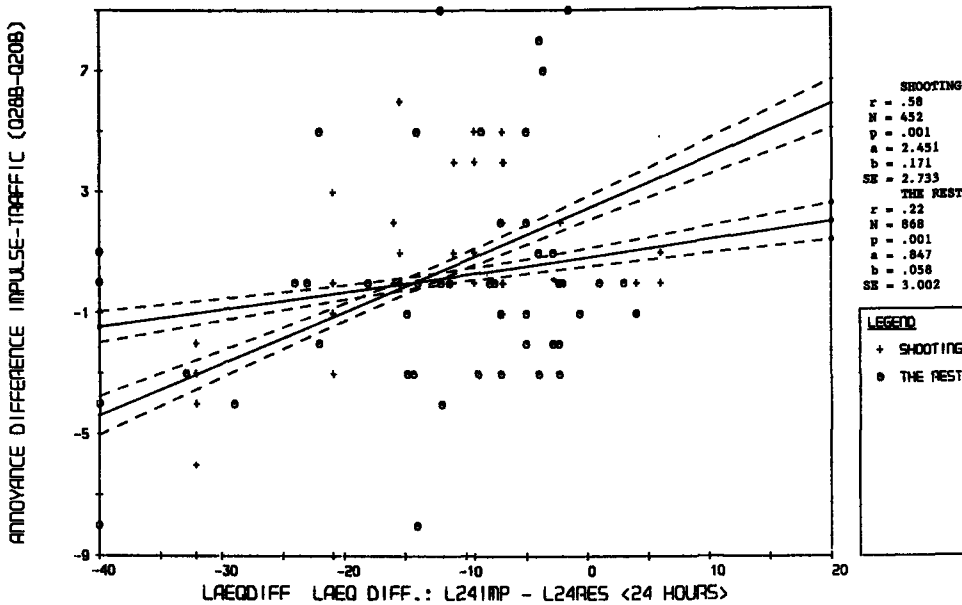
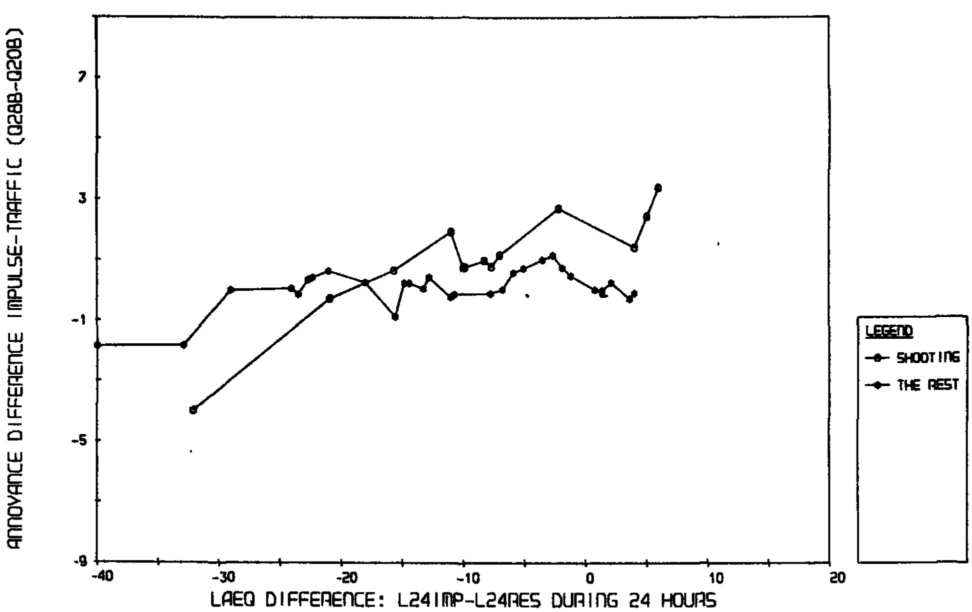


Fig. 12: Difference relation impulse-residual (24 hours).



3.10 MUTUAL INFLUENCES OF NOISES UPON ANNOYANCE

Residual noise levels might influence the annoyance from impulse noise, and impulse noise levels might influence the annoyance from traffic noise.
Both might have any influence upon the deduced penalty.

3.10.1 Influence of residual noise on impulse noise annoyance

In the national reports from Germany, Ireland and the Netherlands the influence of residual noise has been discussed.
From the combined data from all countries (including France) the overall influence has also been determined. The conclusions are rather contradictory.
For both Germany and Ireland the results are pointing towards a larger penalty with higher (≧ 55 dB(A)) residual noise levels (during operation time) supporting a stress or accumulative theory. For the Netherlands several results are not quite in accordance with each other and no conclusions have been drawn. In France nearly all respondents are exposed to higher residual noise levels, which makes it impossible to carry out the analysis.
The overall influence of residual noise upon the dose-response relation for impulse noise as well as upon the penalty, deduced from the difference relation, has been investigated by discriminating two groups of residual noise levels, one with levels lower than 55 dB(A) and one with levels equal to or higher than 55 dB(A). Dose-response relations for impulse noise for each of the two groups have been determined as linear regression lines, with their 95% confidence intervals, using noise levels during operation time in Figure 13, and using noise levels during 24 hours in Figure 14.

Fig. 13: Dose-response relation impulse noise (operation).

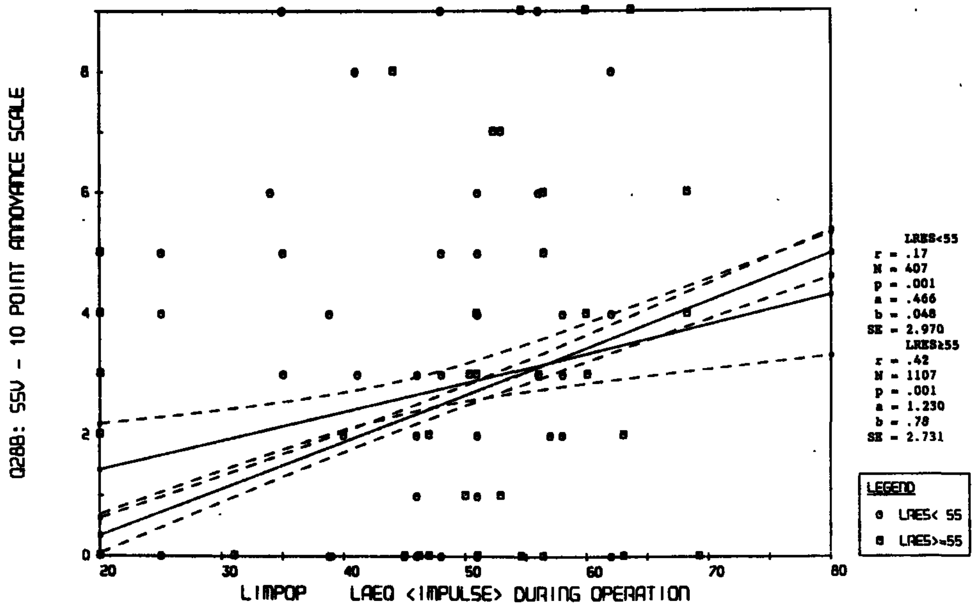


Fig. 14: Dose-response relation impulse noise (24 hours).

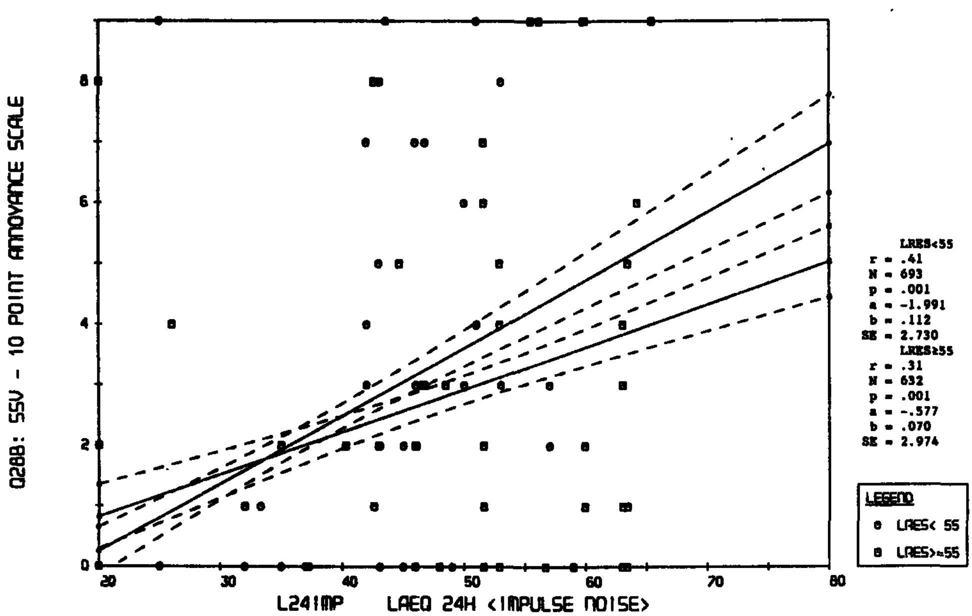


Figure 14 (with 24-hour noise levels) shows a difference valid for impulse noise levels higher than about 40 dB(A). This implies that (above about 40 dB(A)) the impulse noise is less annoying with higher residual noise levels than with lower ones. This would support a masking theory: higher residual noise levels induce a decrease of annoyance from impulse noise.
However, from Figure 13 (with operation time noise levels) one obtains an opposite impression. There exists a (slight) difference between both discriminated groups below about 50 dB(A), where impulse noise annoyance is higher with lower residual noise levels. In both figures the apparent interaction between both groups is opposite to each other, only resulting from different integration times for equivalent noise levels. As a result firm conclusions cannot be drawn.
Examining the influence of residual noise upon the value of the penalty for all countries together difference relations (as described in 3.6) have been determined for the two discriminated groups of respondents. They are presented as linear regression lines in Figure 15 with operation time noise levels and in Figure 16 with 24-hour noise levels.

From Figure 15 no difference at all between both groups emerges, for noise levels during 24 hour (Figure 16) it is quite clearly visible that the regression line for the lower residual level group has a steeper slope and thus represents a stronger relation than the higher residual level group in which the difference in annoyance apparently is less dependent upon the difference in noise levels. Despite this difference between both groups, their regression lines cut each other just at the point where the annoyance difference is about zero. This results in the same, not differing, penalty for both groups, the same result as obtained with noise levels during operation time. So it is not possible to conclude to essential differences between both groups.

Fig. 15: Difference relation impulse-residual (operation).

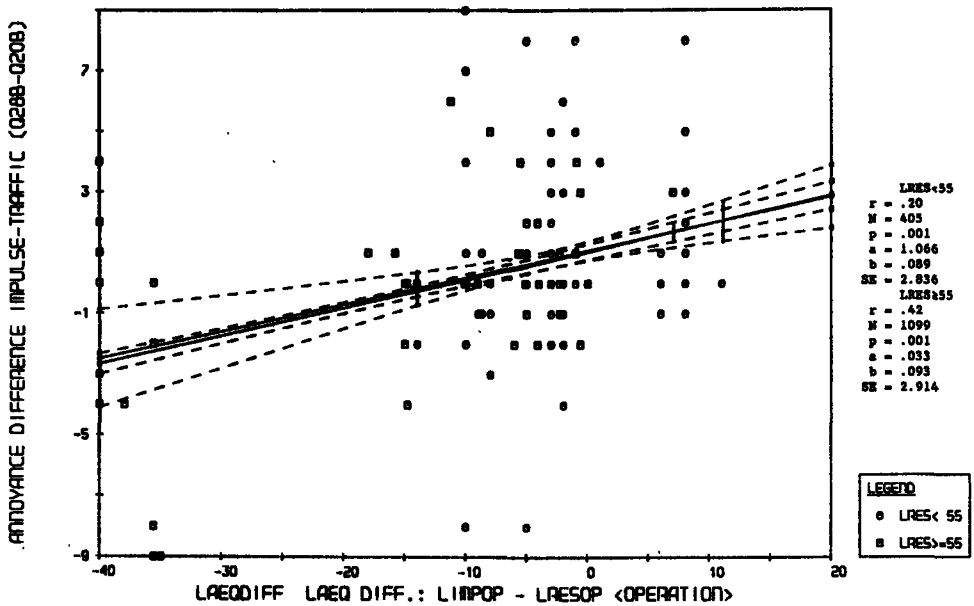
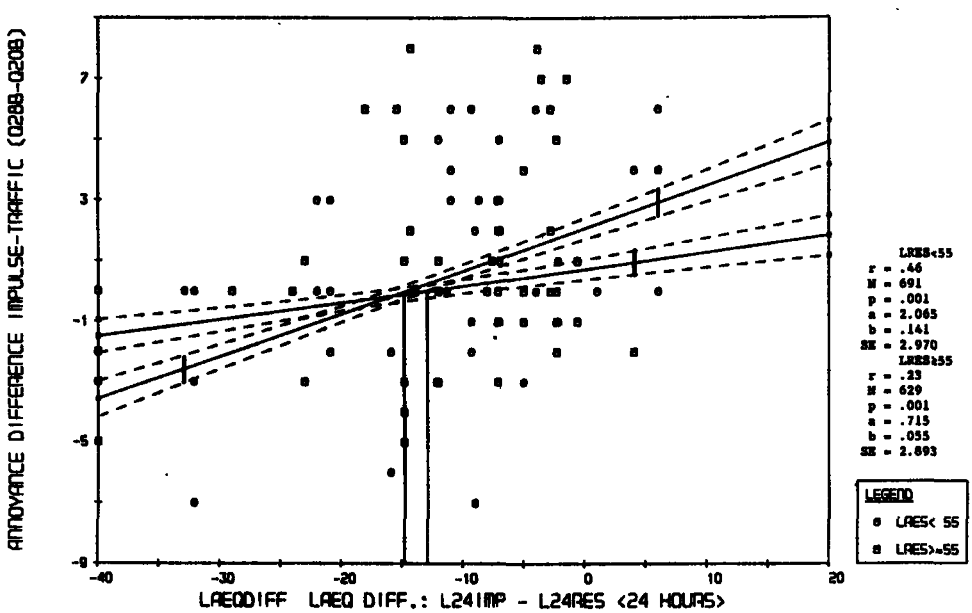


Fig. 16: Difference relation impulse-residual (24 hours).



Apparently the French data, which mostly consist of only the higher noise level group, cause the difference between both groups, concerning the deduced penalty, to have vanished. Including French data the analysis neutralizes the results from Germany and Ireland or even suggests an opposite conclusion. A possible explanation for this effect has already been mentioned in section 3.7, when discussing the rather high degree of annoyance in France from residual noise, used as the reference and its resulting much lower penalty for impulse noise in France.
Alternatively, the point to discriminate between lower and higher residual noise levels was chosen varyingly, relative to the difference between impulse and residual noise levels. The lower residual noise level group consisted of situations (respondents or zones) were the residual noise levels were less than the impulse noise levels plus 10 dB(A). The rest formed the higher residual noise level group.

The relative difference discriminating the two groups of 10 dB(A) has been chosen for two reasons: firstly because it is about equal to the minimum penalty already found and secondly in order to obtain groups in which the number of respondents would not differ too much.

Establishing difference relations separately for these groups should be considered senseless because the independent variable in these relations is the same as the controlling factor, it is the variable at which the two groups are discriminated (the difference between the impulse and residual noise levels). Therefore only the impulse dose-response relations have been regarded, presented in Figures 17 and 18, showing linear regression lines using noise levels during operation time (Figure 17) as well as during 24 hours (Figure 18).
From these figures it is clear that the group with relatively lower residual noise levels scores higher impulse noise annoyance than the group with relatively higher residual noise levels.
The effect found here supports the masking model.
How this effect is present in each country has only been investigated in the Netherlands, where it was difficult to interprete due to the different impulse noise level ranges found for the two groups.

Fig. 17: **Dose-response relation impulse noise (operation).**

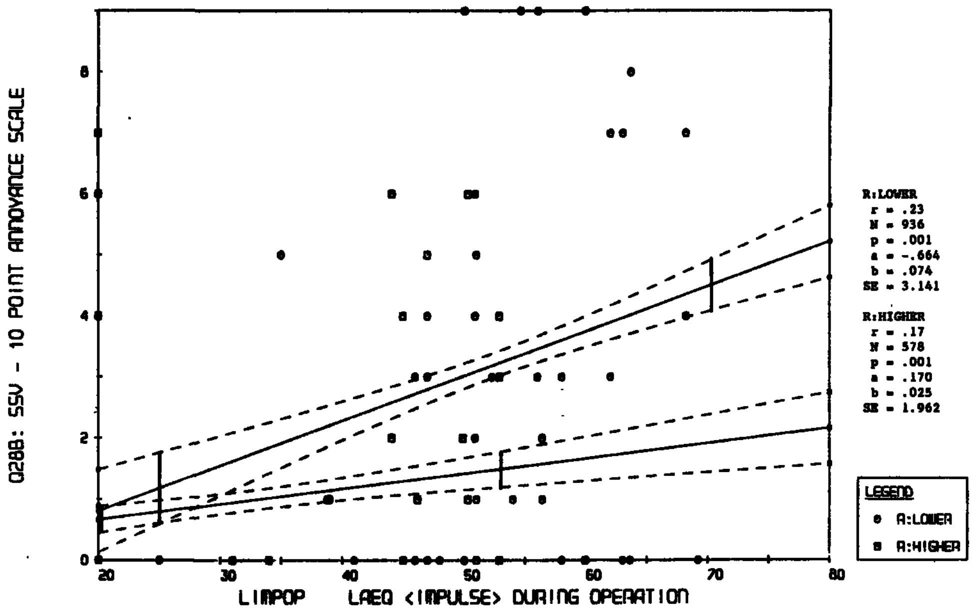
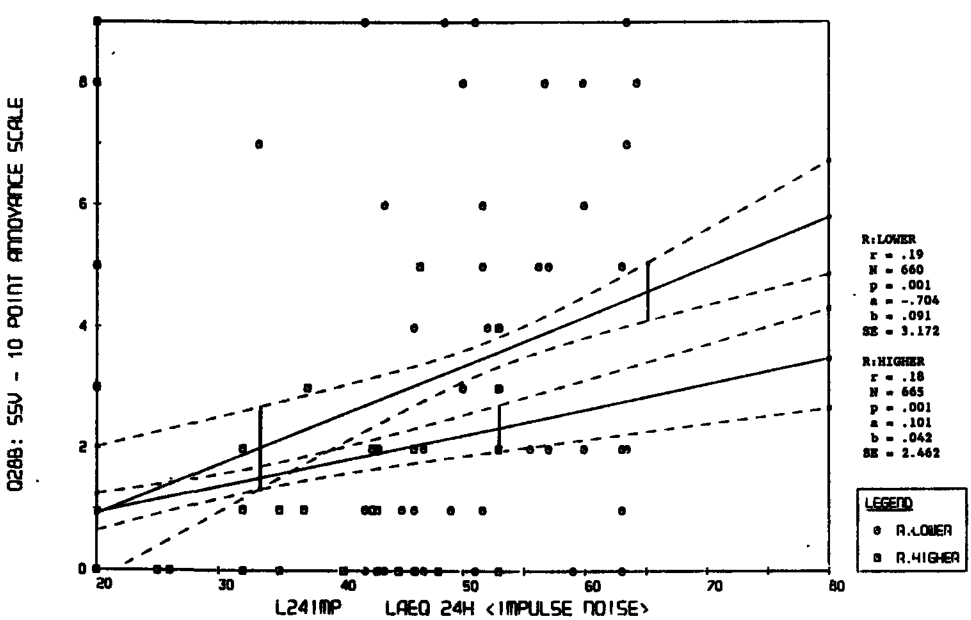


Fig. 18: **Dose-response relation impulse noise (24 hours).**



3.10.2 Influence of impulse noise on residual noise annoyance

The influence of impulse noise upon residual noise annoyance and the difference relation was examined similarly using two groups, one with impulse noise levels lower than or equal to 45 dB(A) and another with higher levels. Dose-response relations with both operation time and 24-hour noise levels yielded the same interaction as shown in Figure 13: higher impulse noise levels strengthened the residual dose-response relation in all respects. That is to say, higher impulse noise levels caused less traffic annoyance at lower residual noise levels and more annoyance at higher levels than lower impulse noise levels. With higher impulse noise levels the dose-response relation for residual noise has a higher correlation and a steeper slope.
With similar difference relations no differences between the groups were found, and no figures are presented here (only Figure 28 in section 3.14). This implies that any penalty should be regarded appropriately at any impulse noise level.
In the Irish national report different penalties are discussed in this case, a larger penalty with lower impulse noise levels than with higher ones. Separate analysis on Dutch data yields a weak indication for the opposite effect, while the French and German reports do not mention any such investigation.
Regarding all conclusions within this section, being discrepant in some instances, we might say that the influence of a noise upon the annoyance from the other is unclear and has to be determined more thoroughly yet, mainly by the way of multiple regression analysis.
Using methods described up to now, results apparently very much depend on the method itself and the absolute (or relative) values at which groups are discriminated (see also the Dutch national report).

3.11 INTERVENING FACTORS

The influence of the following intervening variables upon dose-response relations and difference relations has been investigated: sex, age, profession, satisfaction with area in general, being a house owner or renter, education, number of children, (economic) ties to the impulse noise source and the number of working hours of the impulse noise source.

For most of these no or hardly any effects upon dose-response relations appeared and even when slightly present, effects upon difference relations were mainly absent or negligible due to the fact that intervening influences may be regarded as eliminated in a repeated measures design.
This expectation has already been discussed previously. It means that penalties obtained are practically independent of intervening influences.
The only factor having a strong influence on all dose-response relations is the satisfaction with the area in general: the less satisfied the more annoyed respondents are and vice versa.
This effect was clearly demonstrated in Figures 19 and 20 serving as examples from many similar Figures such as 27. Figure 19 shows the dose-response relations of total noise with noise levels during operation time as smooth curves and Figure 20 gives linear regression lines representing dose-response relations for impulse noise with operation time noise levels too. In this last example the relations for the satisfaction levels NEUTRAL and VERY SATISFIED are approximately the same. Upon not presented residual dose response relations the influence is also present though somewhat less pronounced.

Fig. 19: Dose-response relation total noise (operation).

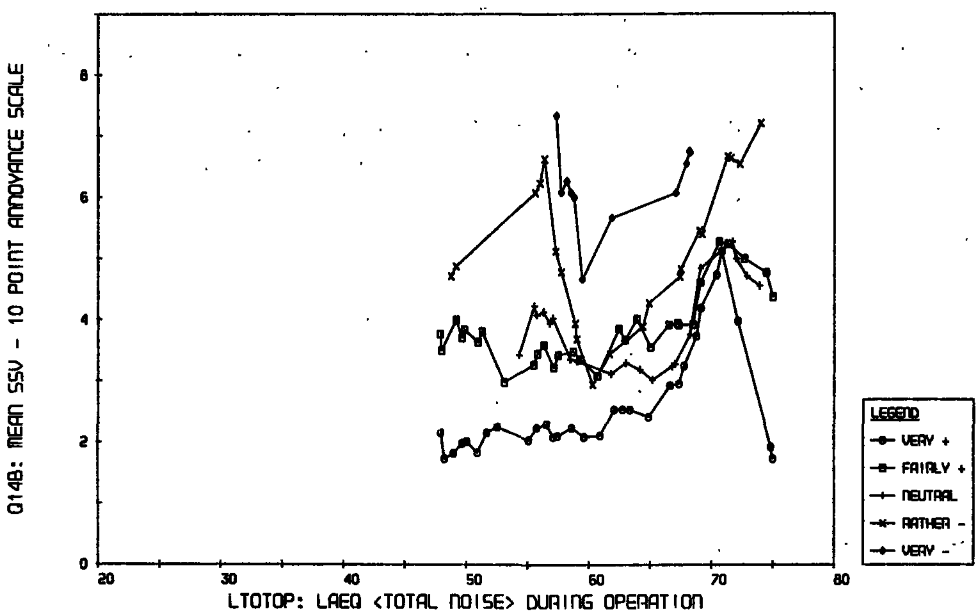
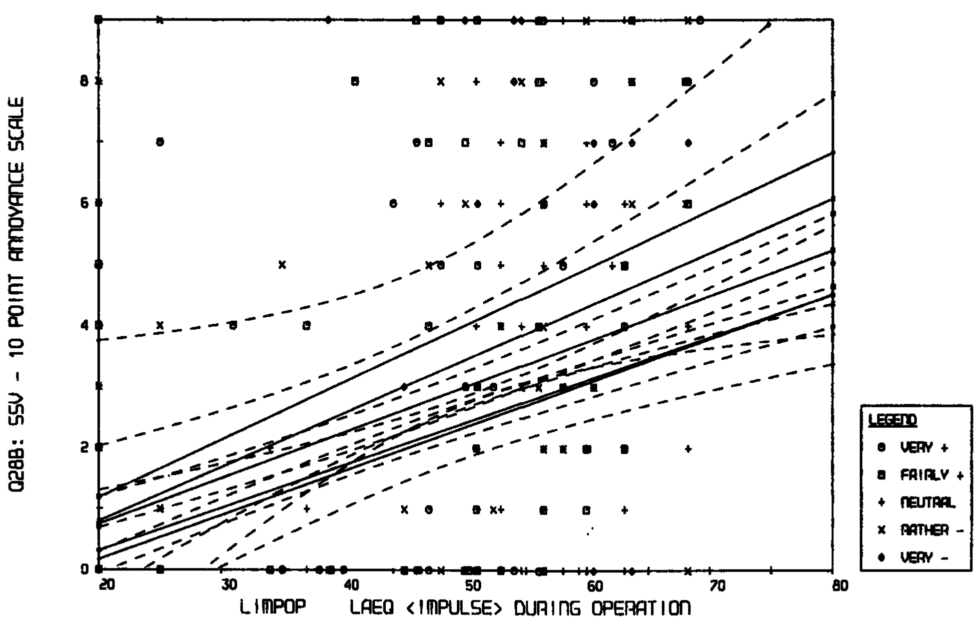


Fig. 20: Dose-response relation impulse noise (operation).



Some very slight, but present effects appeared with the following remaining intervening variables:

a. Sex: Women are slightly more annoyed by impulse noise than men and appear to have a somewhat larger penalty for impulse noise (based upon operation time levels).

b. Age: Generally young (18-25 years old), but especially old (above 65 years) people are somewhat less annoyed than others.

c. Profession: Students and retired people are slightly less annoyed than other people (cf. Age!).

d. House owners are a little more annoyed than house renters (at lower noise levels).

e. Education (see for definition section 3.2): Higher educated people experience somewhat more annoyance than lower educated ones.

f. Number of children: Only from impulse noise people with no or only one child were somewhat less annoyed than people with more children.

g. (Economic) ties: hardly different. For the few people (Table 7) with ties the penalty could be slightly smaller.

h. Number of working hours: Operation times of 4 hours and less (mainly shooting ranges) induced a little less impulse noise annoyance (Figures 29 and 30 in section 3.14 do not illustrate this clearly).

Other possible intervening factors such as deafness, understanding the questions and diverse opinions concerning the living situation have not been analyzed.

3.12 INFLUENCES ON THE SIZE OF THE PENALTY

The size of the penalty for impulse noise compared to (more or less continuous) traffic (residual) noise can be stated to be at least 10 dB(A). Above this value variations are possible depending upon several influencing factors such as:

a. the measure with which the noise is described. In this study the L_{Aeq} 24 h yields an about 3 dB(A) higher penalty than the L_{Aeq} operation time.

b. the value at which lowest absolute noise levels are fixed (10, 20 or 30 dB(A)) if those levels are too low to be measured.
These influences are quite small, maximally about 2 dB(A) with a 10 dB(A) difference between lowest noise levels.

c. the influence of residual noise upon the penalty still has to be examined more thoroughly using multiple regression analysis.

Ad. b

In section 3.4 it was already stipulated that lowest noise levels, too low to be heard or measured were set at 20 dB(A), which is a rough estimate of the real levels. This was not done in ceses where those (impulse) noise levels could not be measured due to much higher other present (residual) noise levels, but where those lower levels surely were much higher than 20 dB(A), as occurred in Germany. In such instances the lower noise levels, if it was not possible to estimate them reliably, were defined as unknown and were not used in relational analysis.
As the 20 dB(A) is only a rough estimate, it was worth the trouble to investigate the influence of several other different realistic values to define these lowest noise levels with. Instead of 20, levels of both 10 dB(A) and 30 dB(A) were used and penalties deduced.
It appeared that, through these values deviated ±10 dB(A) from the initial 20 dB(A), the emerged penalties deviated by no more than ± 2 dB(A), which is even less than the accuracy of the penalty already presented. Thus the influence of defining lowest noise levels at different, though possible, values upon the emerging penalty is negligible.

3.13 DOSE-RESPONSE RELATIONS CONCERNING DISTURBANCES

Besides the annoyance questions already discussed, the questionnaire also contained ten questions concerning several kinds of disturbances caused by the traffic noise (Q 21) and the impulse noise (Q 29). Answer categories to these questions were: OFTEN, SOMETIMES, SELDOM or NEVER disturbed. The results related to the noise levels, not as mean disturbances from the four disturbance levels but as percentages of disturbances for a given noise level, using the SSCM described in Appendix 3. Three different percentages are regarded:

a. the percentage of OFTEN disturbed people for a given disturbance item,
b. the cumulative percentage of OFTEN + SOMETIMES disturbed people and
c. the cumulative percentage of OFTEN, SOMETIMES + SELDOM disturbed people, leaving out the percentage of NEVER disturbed people.

Apart from these percentages also a percentage of people is presented reporting to hear the noise in question, for given noise levels.

Figures 21, 22 and 23 contain percentages of people hearing the traffic noise and being disturbed by it with regard to all ten different possible disturbances, dependent upon residual noise levels during 24 hours. Figure 21 presents the percentage of people often disturbed, Figure 22 presents the cumulative percentage of pople often and sometimes disturbed and Figure 23 presents the cumulative percentage of people often and sometimes and seldom disturbed.

Figures 24, 25 and 26 are similar to the above described figures, but concern impulse noise instead of traffic noise and impulse noise levels during operation time instead of residual noise levels during 24 hours.

Fig. 21: Percentage of people disturbed by traffic noise

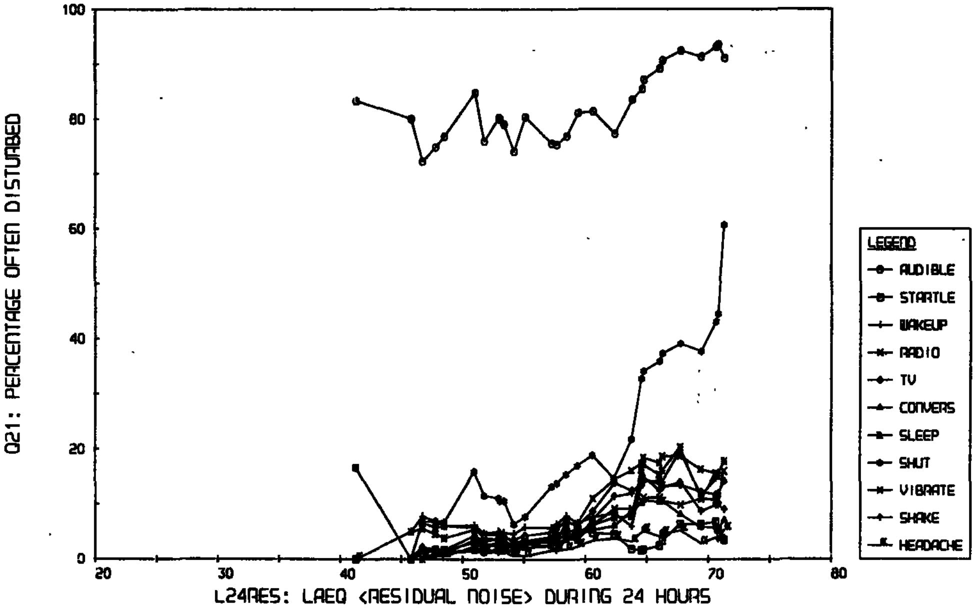


Fig. 22: Percentage of people disturbed by traffic noise.

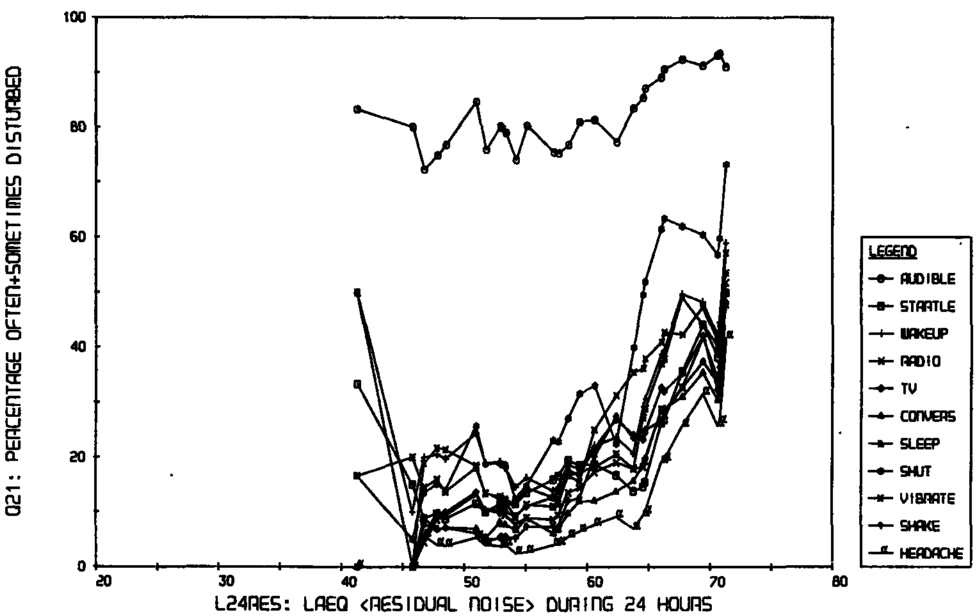


Fig. 23: Percentage of people disturbed by traffic noise.

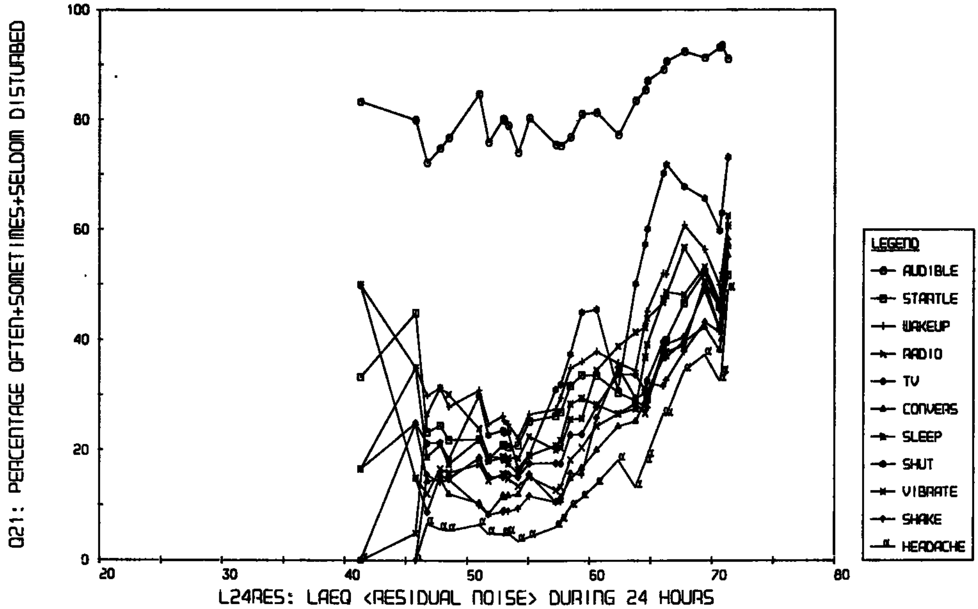


Fig. 24: Percentage of people disturbed by impulse noise.

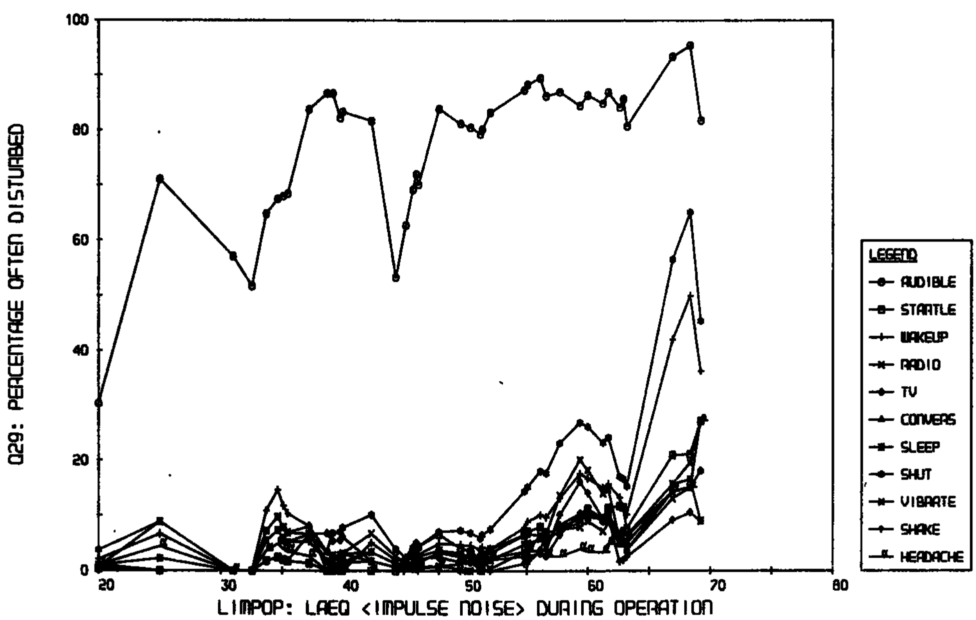


Fig. 25: Percentage of people disturbed by impulse noise.

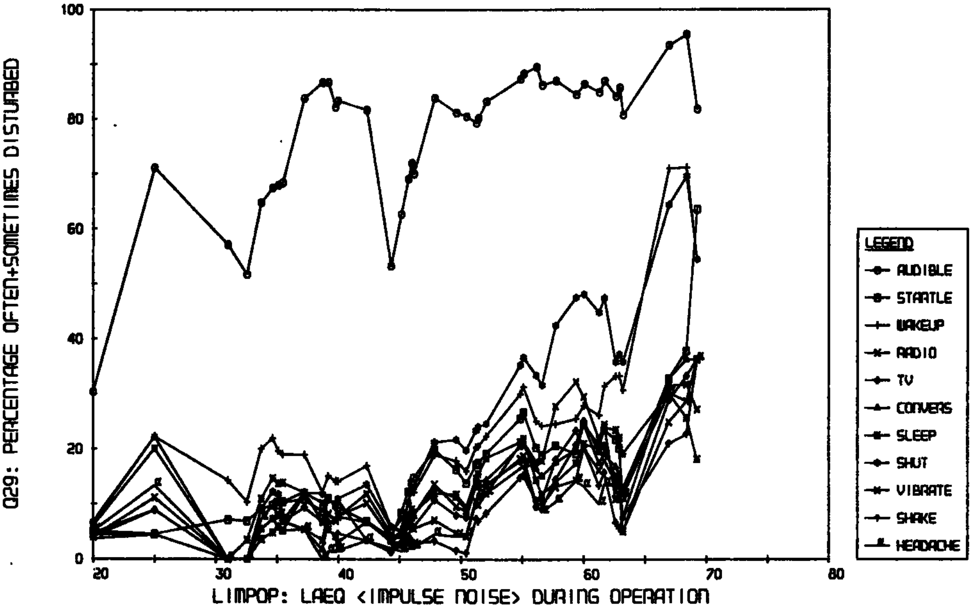
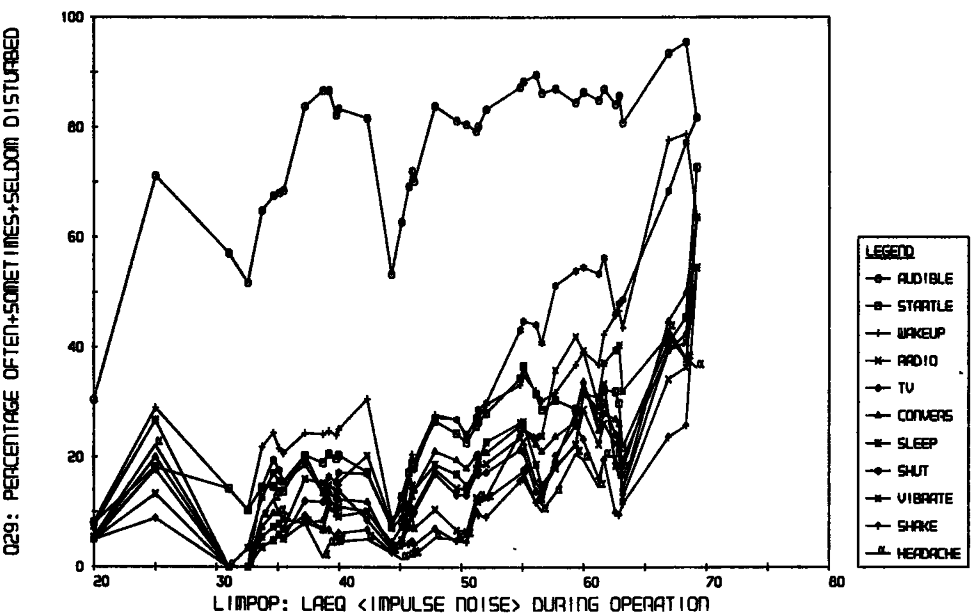


Fig. 26: Percentage of people disturbed by impulse noise.



From Figures 21, 22 and 23 concerning traffic noise the following may be observed:

a. hearing traffic noise appears to be positively related to the corresponding residual noise levels during 24 hours only above about 63 dB(A). The same can be stated for relations based upon residual noise levels during operation time (no figures presented).

b. both with residual noise levels during 24 hours and those during operation time the percentages of disturbances generally are covariant with the percentage of hearing of the (traffic) noise, that is, the presented disturbance relations show a similar pattern as the hearing relation. So disturbances appear to be also rather independent of the noise level at lower noise levels and dependent on it at higher levels.

c. the most disturbing factor experienced from traffic noise is <u>having to shut doors and windows</u>, the next most disturbing one (though less clear) <u>is being waked up</u>, the least disturbing one is getting a <u>headache</u>. For the three different (cumulative) percentages the <u>rank</u> order of the disturbances according to their percentages can be somewhat different. For example, <u>being startled</u> is one of the least "often" experienced disturbances, while it belongs to the five factors experienced as "often - sometimes - seldom" disturbing. Between other disturbances there are hardly any differences.

From Figures 24, 25 and 26 concerning impulse noise slightly different observations are obtained:

a. hearing the impulse noise on the average is positively related to the corresponding impulse noise levels during operation time, though the relation fluctuates very much. Using impulse noise levels during 24 hours yields a nicer relation (though not presented).

b. disturbances from impulse noise are similarly rather well related to hearing impulse noise, both for operation time and 24-hour noise levels. Thus generally, the disturbances are also positively related to the impulse noise levels, especially at higher levels.

c. the most disturbing factor experienced from the impulse noise is the same as from traffic noise: having to shut doors and windows, followed by being waked up. Other disturbances are experienced more or less to the same extent, though differences between most and least experienced disturbances are evident.
Getting a headache is not the only disturbance experienced relatively less, another one is the *shaking of things inside one's house*.

Comparing the Figures 21, 22 and 23 with the Figures 24, 25 and 26 a clear difference arises between road traffic noise and impulse noise regarding the relative disturbances they evoke. While both types of noises cause headache as the least disturbing factor and having to shut doors and windows and being waked up as the most disturbing factors, vibrations are experienced as relatively very disturbing with traffic (residual) noise and as relatively little disturbing with impulse noise.

When compared absolutely the audibility and the disturbances experienced from both traffic and impulse noise are, within the common noise level range (of operation time and 24-hour noise levels), of about an equal size, expressed as percentages. That is, generally both noises cause the same amount of disturbance at similar noise levels. Due to the different noise level ranges for both noises, however, the percentages of people hearing them differs, as can be seen from Table 7.

3.14 SHAPE OF SMOOTH DOSE-RESPONSE RELATIONS AT HIGH NOISE LEVELS

Observing Figure 1, the dose-response relations for all three noises with noise levels during operation time, it is quite remarkable that at the highest noise levels, say around 70 dB(A), the annoyance tends to decrease. This phenomenon is less clear to observe from Figure 2 with operation time noise levels and also less clear from dose-response relations per country (Figures 5, 6 and 7), because these relations already fluctuate rather much.
Nevertheless, the tendency has been observed. Other studies on noise annoyance, carried out by the IMG-TNO and using the SSCM, also sometimes yielded figures in which this phenomenon occurred [14], [15].
In any case it concerned noise levels of around or above 70 dB(A) at which the annoyance appeared to be reduced. Explanations of this effect at the moment are only hypothetical. Possible explanations are:

a. self-regulating effects: at these very high noise levels, with which much and increasing annoyance would be expected, the annoyance might be so inacceptably high, that people undertake actions to avoid the noise, e.g. by moving. The result would be that there would be few people exposed to those high noise levels, which would experience the corresponding high annoyance expected too. This would leave only those people who would (report to) experience only less annoyance.

b. sound-insulating measures: it is quite possible, though not analysed in this study, that dwellings exposed to such high noise levels are already provided with good sound insulating measures or windows are kept closed, thus reducing the noise annoyance experienced at home.

c. different response criteria: annoyance being reported does not necessarily represent the annoyance experienced. Annoyance by a noise can either be strengthened or weakened by the presence of a second source or the same source in a different situation (inside-outside) or still other factors. Two main causes are possible: masking (by another noise) weakens the annoyance from a certain noise and a change in the respondents sensitivity to noise influences his annoyance in anyway.

d. range effects of the scale used: it is possible, though not easily verifiable, that the upper end of the ten-point annoyance scale used is a limit. On an average this limit is already reached at somewhat lower noise levels. However, this explanation would be expected only to cause an equalizing effect on annoyance, not a decrease.

Maybe more explanations are possible and maybe combinations of explanations are likely. Anyway, while these explanations would apply to the annoyance, regarded as a subjective response, or disturbances, regarded as more objective responses to specific situations, explanation c (and perhaps d concerning a four-point scale) would not be valid, and the phenomenon would be expected to be less visible in the disturbance relations (Figure 21 to 26), which already fluctuate rather much and from which the hearing curve would also show the effect.

However, the intervening variable "satisfaction with the area in general", influencing the dose-response relations quite strongly (Figure 19) apparently is also well-related to the effect discussed in this section. At each

degree of satisfaction the effect does not appear to the same extent, but differs per degree as far as those high noise levels are included. With very satisfied people the effect appears to be strongest, with fairly satisfied and neutral people the effect is present but less pronounced, and with rather satisfied people the effect is absent. This would point to a relation between the effect and the satisfaction with the area in general, direct or indirect. Yet, with this relation it is possible to support both explanations a and b, but certainly not c and d. Similar to Figure 19, concerning total noise, Figure 27, concerning residual noise, shows the same phenomenon, though it contains other fluctuations too, which are not interpretable at this moment.
Relations with other intervening factors in these cases also show the phenomenon, though hardly or not discriminative to different levels of the intervening factors. A further search for situations in which the effect mainly occurs yields discriminating magnitudes of the effect for different levels of some other controlling variables:

a. Figure 28 presents the dose-response relation for residual noise using noise levels during 24 hours, discriminating between impulse noise levels (during 24 hours) lower and higher than 45 dB(A). Though on an average there is no difference between both groups of impulse noise levels, at the highest levels the phenomenon discussed appears to be present to a different extent for each of the groups. The effect appears to be strongest (for residual noise here) in situations where the impulse noise is higher than 45 dB(A). This might support explanation c mentioned before concerning the use of different response criteria by respondents when judging (unwillingly) noises relative to each other.

b. Figures 29 and 30 present dose-response relations for impulsive noise, in Figure 29 with operation time noise levels and in Figure 30 with 24-hour noise levels, discriminating between different numbers of working hours of the impulse noise sources. From both figures the phenomenon seems evident for each of the discriminated categories of working hours, though the effect with impulse noise in Figure 1 (the total effect) is only due to the medium range of working hours in Figure 29. The less clearly visible effect with impulse noise in Figure 2 appears more clearly when discriminating between working hours in Figure 30, though not strongly convincing.

c. Figures 31 and 32 present the same relations as Figures 29 and 30 respectively, but discriminating between types of impulse noise sources. The total effect with impulse noise, visible in Figure 1, appears to consist of mainly scrapyards, which apparently produce the very high noise levels. When disregarding the other fluctuations the effect seems also present with metal working sources at a lower noise level. Figure 32 is as illustrating as Figure 31 whereas the corresponding Figures 2 and 1 (without source discrimination) are not. Apparently Figure 2 shows the phenomenon less clearly because of the influence of the shunting yard in Figure 32.

Finally, combining the former considerations, it might be stated carefully that the phenomenon described is visible sometimes and is related to the respondent's satisfaction with the area and that where it is present with impulse noise it is mainly due to situations with scrapyards with normal working hours. This does not imply that other impulse noise sources would not show the phenomenon, but in this study the other sources do not produce the (necessary) high noise levels to investigate the effect.

Fig. 27: Dose-response relation residual noise (operation).

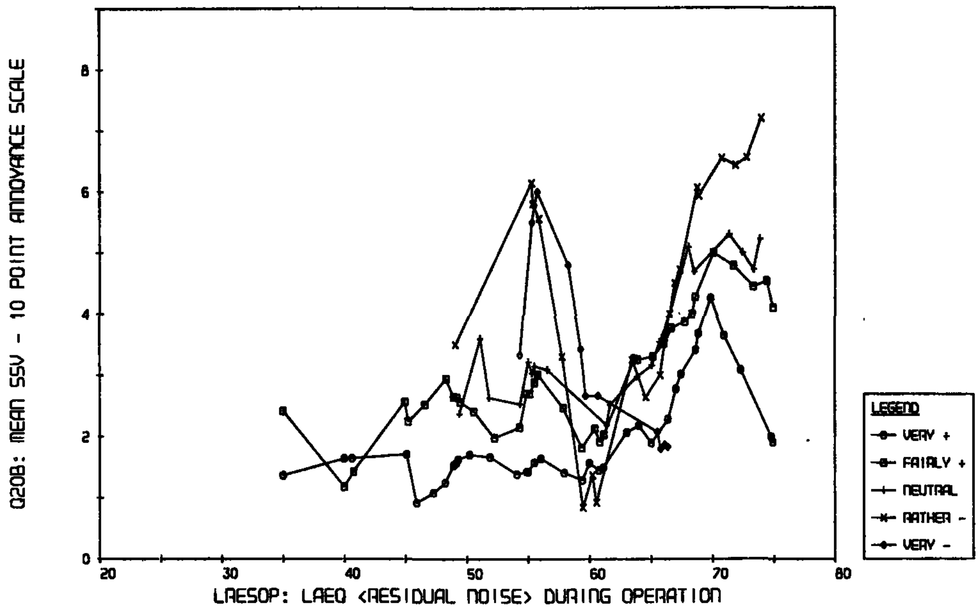


Fig. 28: Dose-response relation residual noise (24 hours).

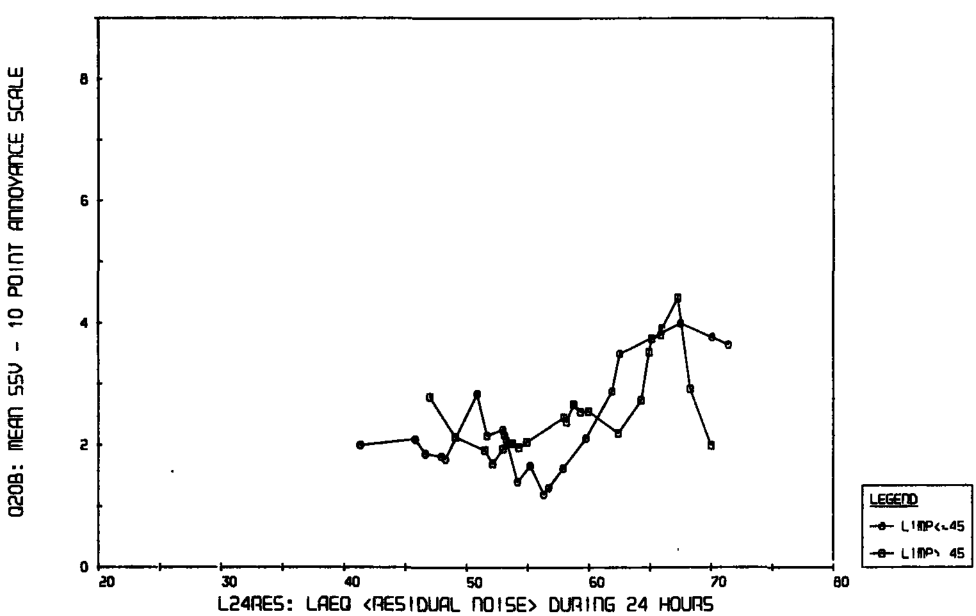


Fig. 29: Dose-response relation impulse noise (operation).

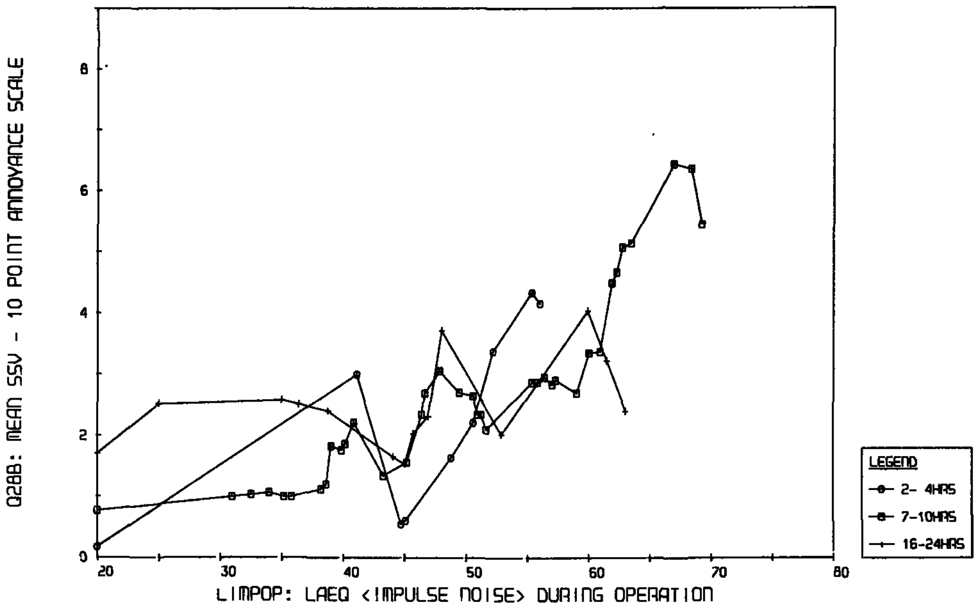


Fig. 30: Dose-response relation impulse noise (24 hours).

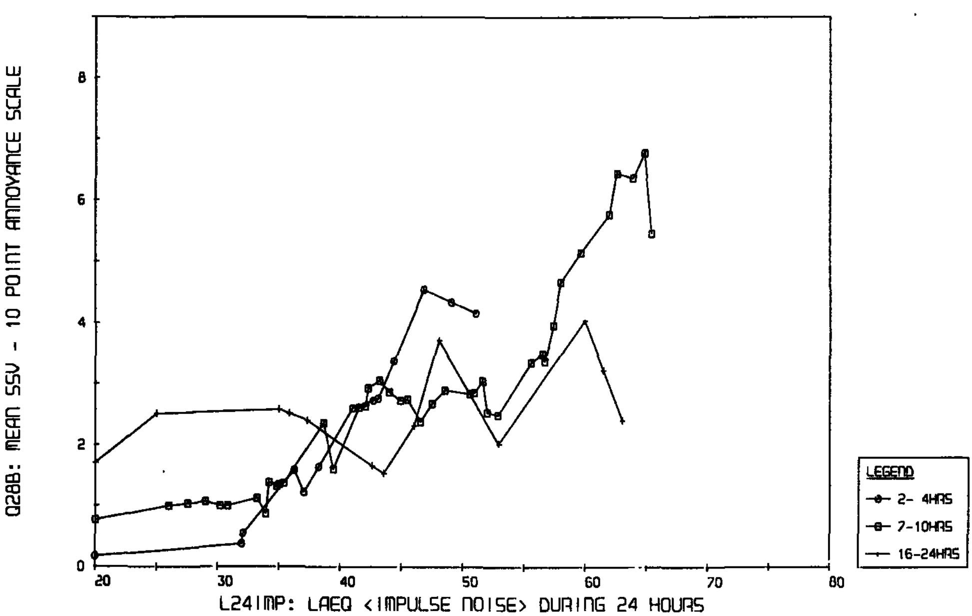


Fig. 31: Dose-response relation impulse noise (operation).

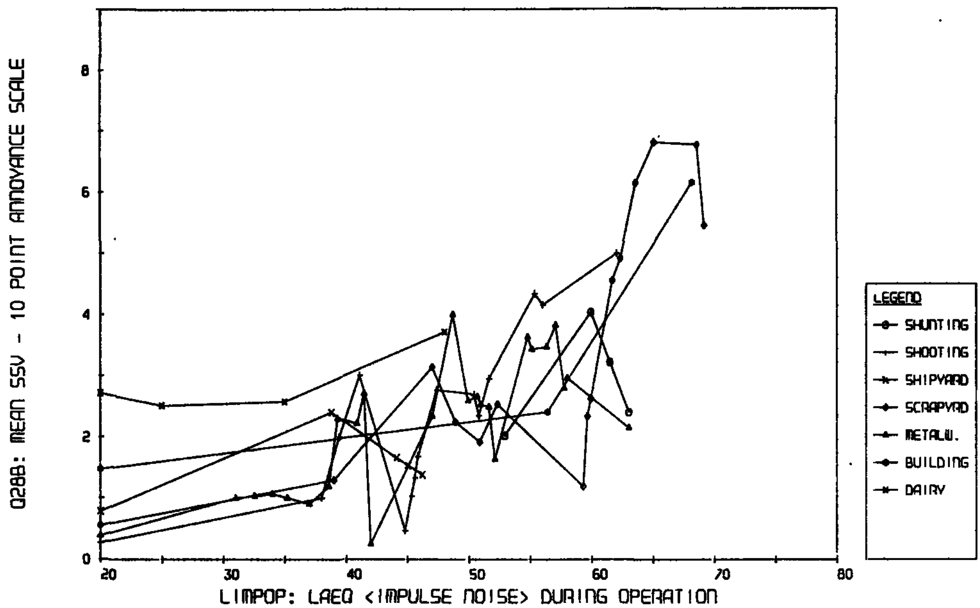
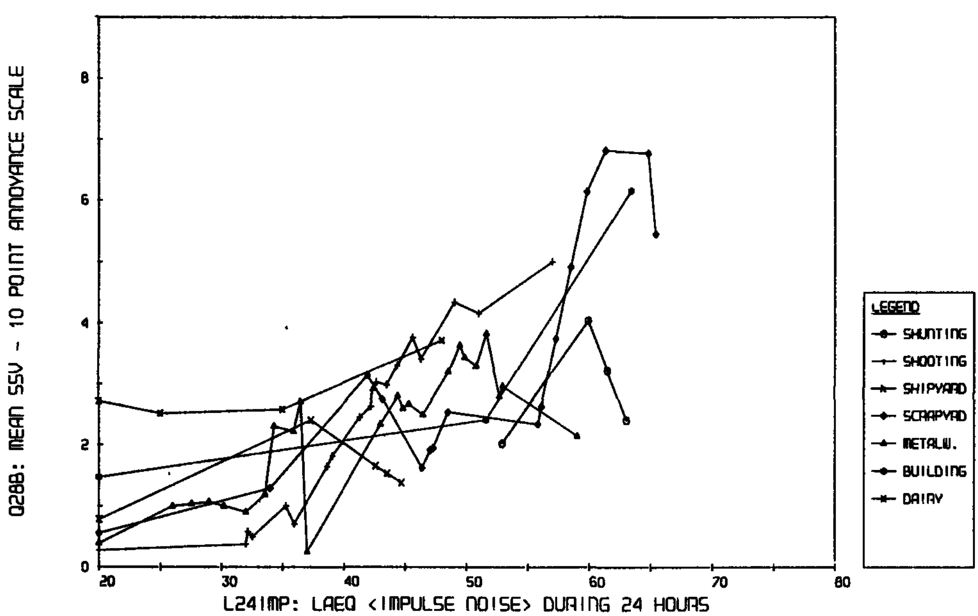


Fig. 32: Dose-response relation impulse noise (24 hours).



4. CONSTRUCTION OF A MODEL FOR PREDICTING ANNOYANCE CAUSED BY TWO NOISE SOURCES

4.1 GENERAL

Up to now much research has been carried out to establish dose-response relations for single noise sources. From these relations norms, used in legislation, have been derived. However, in everyday life people are seldom exposed to only one source. When more than one source is present, both researchers and administrators are faced with the question how to weight the influence of both sources against each other. In the course of time some, first attempts have been made to offer solutions to this question. From socio-psychological theories three basic models were derived: the average, dominant and additive model.
They will be tested with the data accumulated in this project. Also some models derived from the basic models will be tested. First a very short description of the basic models and the models derived from them will be given.

4.2 DESCRIPTION OF THE MODELS

In section 3.10 a cumulative theory has been mentioned in relation to the influence of residual noise upon impulse noise annoyance and the other way round. It assumes that the annoyance from a certain noise is also determined by the amount of different noise via the annoyance from that noise. Thus the impulse noise annoyance would be influenced directly to a certain extent by traffic noise annoyance and vice versa. The magnitude and the direction of the influence would be dependent upon the site of both annoyances. It is not possible to examine direct relations between traffic and impulse noise annoyance other than in the way described in section 3.10 using discriminated groups with lower and higher (residual) noise levels or otherwise by relating the annoyance from the three noises to noise levels of only one of the noises, thus enabling comparisons and relations between annoyances as has already been described in the Dutch national report [7].
It is possible, however, to determine directly the influence of traffic and impulse noise annoyance upon the total noise annoyance, which might be considered to be composed of all noises present mainly residual and impulse noise. Because other noises may play a part too and because the

total noise annoyance question has not been posed explicitely a very clear relation will not be expected. Yet, establishing this relation, or alternatively, assuming relations based upon different cumulative models and searching for the best fitting one may give some insight into cumulative effects of annoyance (and with that of noise). It is assumed that on an average the influences of both "partial" annoyances are equally strong. This assumption makes multiple regression analysis redundant. The question is how do the partial annoyances co-operate to result in a total annoyance? Do they (at a specific ratio scale as the used 10-point scale might be considered) just add to each other, or subtract, or average or does the highest one dominate? In the Dutch national report [7] a train of thoughts has been described leading to the testing of the ADDITIVE, the DOMINANT and the AVERAGE models.

The additive model assumes summing of two (or more) partial annoyances, the dominant model assumes the highest annoyance to be the total result and the average model assumes averaging the annoyance sizes. The average model would lead to a decrease of total annoyance, when a noise causing less annoyance itself would be added to already present noise(s). This does not seem very realistic. The dominant model would indicate that the total annoyance not would increase even if many noises with each the same annoyance would be added to already existing noise(s). This equally does not seem very realistic. The additive model adding both sizes of partial annoyance seems too crude, especially if (as in this case) the range of the annoyance scale is limited. Therefore some model between the dominant and the additive ones would be expected to be most appropriate.

It can be shown that all models except for the average one are special cases of the so-called Minkovsky distance equation, which formula applied to our case would be:

$$\text{total} = \sqrt[n]{\text{traffic}^n + \text{impulse}^n}$$

in which n is a number between 1 and infinite (∞). The additive model can be described with this formula for n=1 and the dominant one for n=∞.

For n=2 for example, the total annoyance would be equal to the square root of the sum of the squares of the sites of the other source-specific annoyances, as in the Pythagorean theorem.

All models based upon an n between 1 and ∞ are called synergistic models.

Now it is possible to assume several values for n and to test these models in the same way as the other ones.

4.3 TESTING THE MODELS

Apart from calculating expected total annoyance scores based upon the additive, dominant and average model scores have been calculated based upon synergetic models with n=1.2 (SYNERG12), n=1.5 (SYNERG15), n=2 (SYNERG2), n=3 (SYNERG3), n=4 (SYNERG4) and n=5 (SYNERG5) from the traffic impulse annoyance. These expected scores have been compared with observed total annoyance scores in several ways:

a. which model produces the highest correlation coefficient between observed and expected scores?
b. which model generates the highest number of respondents with (about) equal observed and expected scores?
c. which model generates as much as possible similar amounts of expected scores higher and lower than observed scores?
d. which model generates expected scores differing least from observed scores as tested with a paired t test?
   (this method is an alternative to methods b and c)
e. drawing curves per model from mean expected scores per discriminated observed score (0 to 9), which model yields the best fitting curve with the observed one?

ad. a

Correlation coefficients between expected scores from difficult models and observed scores have been calculated and presented in Table 17.
The expected scores from the discriminated models correlate very high between each other: from .93 to 1.00. The correlation coefficients with the observed scores are lower: between .72 and .74, but still rather high. Probably these correlations are not significantly different from each other.

ad. b,c,d

In order to determine when scores are equal and when deviating, it has been defined that scores will be regarded equal if they do not differ by more than one point from the ten-point annoyance scale.

In Table 18 the number and percentages of respondents are presented per model with expected scores lower than, equal to and higher than the observed scores. In addition the t value of differences per model has been included.

ad. b

From the table the DOMINANT model appears to predict the largest number of correct scores for the total annoyance (1075).

ad. c

It is also clear that the DOMINANT model comes closest in producing an equal number of scores lower than or higher than observed scores.

ad. d

The DOMINANT model yields the smallest absolute t value (best would be zero).

ad. b,c,d

Combining the methods of b,c and d the dominant model appears the most correct predictor, though differences with some other models are small.

ad. e

Figure 33 presents curves per model consisting of points connected by straight lines and calculated as mean expected scores for each different total annoyance score. It appears that the dominant curve fits best.

Finally, concluding from these results, it looks best to accept the DOMINANT model as the best predicting one, though it was not expected previously. Maybe it might be interpreted as: adding a noise with equal separate noise annoyance to an already present noise will not increase the total annoyance from both if both noises can be discriminated as different by respondents; if the noises cannot be discriminated they act as only one louder source yielding more annoyance. On the other hand it has also been said that a very clear result would not be expected due to the content of the total annoyance. Though the DOMINANT model should be chosen as the best one, yet it is not the most ideal predictor of total annoyance.

The overall conclusion thus has to read that the dominant model is the best predictor of total annoyance, once the elements of which the total annoyance is composed are known. This is in contradiction to the expectation. However, differences with some other models are small. A weakness in this analysis might be for instance, that "total annoyance" is not defined well enough. Other elements, beside impulse and traffic noise, might have been taken implicitly into account by the respondent. Therefore more research along this line is needed.

4.4 SUGGESTIONS FOR FURTHER ANALYSIS

In order to increase the quality and the value of this kind of analysis we would like to suggest further examination of cumulative effects as they are already presented, repeating the same analysis not for all respondents, but for special cases in order to find possibly better fitting models:

a. only for respondents with (about) equal traffic and impulse annoyance as a special case for which cumulative effects are strongest.
b. only for respondents with traffic and impulse annoyance unequal to zero because all models from DOMINANT ($n=\infty$) to ADDITIVE ($n=1$) do not discriminate between each other in cases where traffic and/or impulse annoyance is equal to zero.
c. only for respondents reporting to have their most important annoyance from traffic and the impulse noise source (Q 13) in order to exclude cumulation influences of other sources and sounds biasing the assumptions of the models that the total annoyance is built from only traffic and impulse annoyance.
d. combination of a and b
e. combination of a and c
f. combination of b and c
g. combination of a, b and c.

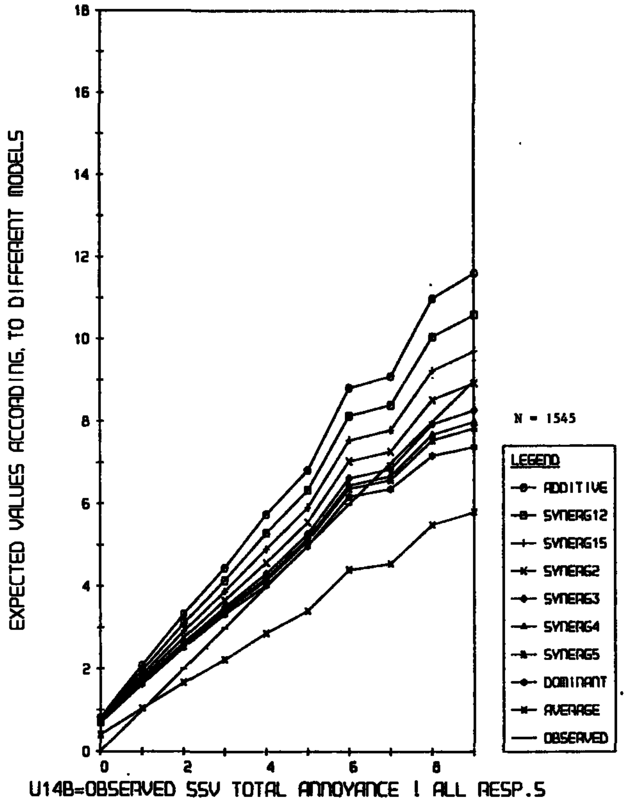
Table 17: Relations between expected and observed total annoyance scores - Pearson correlation coefficients -

Models	Observation
Additive	0.72
Synergistic 1.2	0.73
Synergistic 1.5	0.73
Synergistic 2	0.74
Synergistic 3	0.74
Synergistic 4	0.73
Synergistic 5	0.73
Dominant	0.72
Average	0.72

Table 18: Differences and similarities between observed and expected total annoyance scores
- in percentages (N = 1545), and in t-values

Models	Lower than expected	as expected	higher than expected	t-value
Additive	39	51	10	- 18.2
Synergetic 1.2	36	54	10	- 15.9
Synergetic 1.5	33	57	10	- 13.2
Synergetic 2	29	60	11	- 10.2
Synergetic 3	24	64	12	- 7.2
Synergetic 4	22	66	12	- 5.8
Synergetic 5	19	69	12	- 5.0
Dominant	18	70	12	- 3.0
Average	6	69	25	+ 16.3

Fig. 33: Expected values according to different models.



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ACKNOWLEDGEMENTS

The authors wish to thank all members of the participating teams for the pleasant and stimulating co-operation.
Acknowledgement is also made of the support by the co-ordinator of the laboratory group, C.G. Rice, and of the inspiring discussions with Ph. Cooper and J.G. Walker of the ISVR, D. Commins and A. Germon of Commins bbm and P. Guillot of the C.E.C.

APPENDIX

IDEAS FOR FUTURE RESEARCH

The participating teams feel that a rich and powerful data base has been created. Hundreds of variables about some 1600 respondents, covering 20 aeras with different examples of impulse noise, presenting a good sample of all types of impulse noises, have been accumulated.
The large amount of converging and concurring results convincingly point out the usefulness of international projects like this one.
Strong resemblances of detailed results can be observed in the participating countries, but also some clear differences which still have to be explained.
Against this background some suggestions for future research (programme 1986-1990) are presented.

The first suggestion is to explore the accumulated data base to the full. The analyses carried out up to now and the secondary analyses foreseen in 1984/1985 will by far not exhaust all possibilities to extract more relevant knowledge from this data base. This could be carried out in close connection with the second suggestion: further field studies with the ultimate goal to build models predicting the effect of the presence of two or more noise sources together on human beings.
Several possibilities can be forwarded:

1. Up to now research has been carried out in Germany, France, Ireland and the Netherlands.
   Though we can be confident about the conclusions reached here, results apply only to a few of all countries assembled in the European Community. To gain more confidence, especially about the generalizability of the results, the survey could be extended to other member states.
2. To gain more insight into the role of the level of the residual noise a carefully designed field experiment is needed in which both total noise annoyance and its components are defined neatly. In such an experiment also noise measurements have to be designed carefully: the several components of residual noise have to be identified more precisely than in the previous study and also the place of measurement has to be adjusted.

3. In the previous study residual noise was composed mainly of traffic noise. This has led to a penalty for impulse noise relative to traffic noise.
   For legislative purposes it would be more interesting to study the penalty of industrial impulse noise relative to industrial continuous noise. To be able to use a repeated measurements design (which is a more sophisticated one than a single measurements design) sites should be found in which industrial (more or less) continuous noise forms, to a great extent, the residual noise.
4. Up to now annoyance has been the only effect of impulse noise studied in the field. It would be feasible to explore whether it might be fruitful to study other effects as well, like some physiological effects or other effects related to human health.

The ideas for future research presented above do not exclude each other. Especially the combination of secondary analysis with the points 2 and 3 of the new field studies might prove to be a fruitful combination.

HUISDRUKKERIJ NIPG-TNO

85008
ISBN 90-6743-057-9